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Can We Talk?!

"Publish or perish" is a well-known cliché which nevertheless aptly describes one of the laws of survival in scientific circles. By analogy "communicate or capitulate" ought to be a credo adopted by those research organizations hoping to make science influential in environmental decision making. It is certainly a lesson we are learning at the National Water Research Institute (NWRI). As an integral part of Environment Canada our job is to create and communicate the knowledge and expertise needed to help the department formulate and implement wise environment policies. To do this successfully we have learned that effective communication is essential between the Institute and its important constituencies: the public (through the media and interested citizens); the science and technology community in government, universities and the private sector; and policy makers, regulators and resource managers within government. This publication, "NWRI Digest", is our way of reaching this broad audience with an overview of our activities.

INSIDE

Lake Restoration in Western Canada
Lampricide Safety Assessed
Mirex in St. Lawrence Belugas
Innovation in Ultra-Trace Analysis
Media Backgrounder
The Contaminants Project
The Hydraulics Project
The NWRI Vollenweider Lectureship

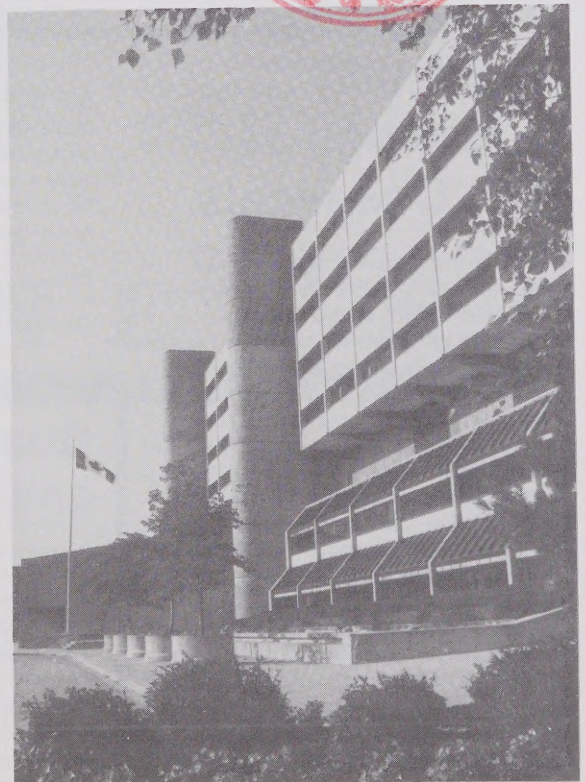
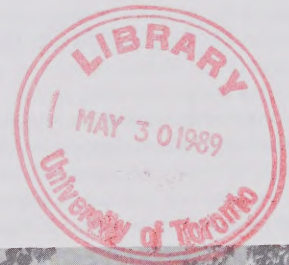
Our goal for the Digest is quite modest. We want to let the people who are important to us know what we are doing on a regular basis and in plain language. By doing this we hope to stimulate dialogue and collaboration which, in turn, will help ensure that we are doing the right research and making it count in decision making.

The format for this inaugural issue changed daily right up to press time. Undoubtedly the look and content of the Digest will continue to evolve in succeeding issues as we experiment and get feedback. Certain things, however, will not change. It will always be inexpensively produced as we want to reach a large audience on a regular basis, and our resources are limited. For the same reasons it will always be relatively brief and to the point. As currently envisioned the Digest will include: brief information items on NWRI activities and achievements; a section devoted to the expressions of ideas or points of view on topics related to the conduct or management of water research; a review of the background behind a few of the NWRI activities which caught the attention of the press and the public over the last few months; and an overview of two of our major research projects.

A small but enthusiastic team of NWRI staff is responsible for developing the concept of the Digest and writing, editing, producing, and distributing the product. They all have other jobs to do and de-

serve a lot of credit for the extra effort they have given to see this first issue published. I am impressed with what they have achieved, but the important opinions are those of the readers and I know that staff will welcome feedback. I hope the Digest will stimulate effective dialogue.

D.L. Egar,
Executive Director



The Canada Centre for Inland Waters, home of the National Water Research Institute

Lake Restoration in Western Canada

Two innovative regional studies of lake restoration techniques are under way in Alberta and British Columbia under the leadership of Dr. T.P. Murphy of the Lakes Research Branch's Lake Restoration Project. These are collaborative studies with several private consulting firms, provincial government agencies, and a university. Major funding has been provided through the Unsolicited Proposals Fund of Supply and Services Canada.

The method being used in the Alberta study is an extension of a lime addition technique developed by Dr. Murphy for suppressing algal blooms. Hydro Qual Consultants of Calgary and Dr. E. Prepas of the University of Alberta are testing the utility of this technique as a replacement for copper sulfate treatment in farm dugouts in Alberta's Peace River country. Copper sulfate usage in the past has created toxicity problems both for livestock and aquatic biota.

Lime addition does two things: it immobilizes some of the toxic copper in the sediments while at the same time precipitating phosphate, the nutrient which causes the nuisance algal blooms. The project is partially funded by the Alberta Ministry of Agriculture.

The British Columbia study is a field evaluation of a novel restoration technique which involves the trapping of nutrient-rich sediments in relatively small holes dredged in sediment accumulation zones in shallow lakes or reservoirs. In Chain Lake, near Princeton, B.C., SciTech Consultants of West Vancouver are investigating the efficiency of a small one-hectare hole, 3-m deep, for trapping nutrient-rich sediments deposited each year. If the "traps" prove to be efficient, sediments can then be treated or removed in a more cost-efficient manner and permanent lake rehabilitation may then result. The dredging has begun and the experiment will take place in the summer 1988. Funding support is being given by the Regional District of Okanagan-Similkameen and the B.C. Ministry of Environment and Parks.

tion, biodegradation, and environmental fate of aliphatic, aromatic, heterocyclic, and organometallic compounds. The effects of various chemicals on species of mammals, fish, zooplankton, phytoplankton, bacteria, and insects are also discussed.

Reference: QSAR in Environmental Toxicology—II. Edited by K.L.E. Kaiser, D. Reidel Publishing Co., Dordrecht, The Netherlands, 465 pp.

Assessing Toxicology of New Chemicals

One of the major tools of environmental toxicology is Quantitative Structure/Activity Relationships which permit the rapid assessment of the environmental and toxicological impact of new compounds being produced by chemical industries. The rate of introduction of chemical compounds exceeds the rate at which their individual impacts can be assessed. By establishing relationships between molecular structure, physiological effects, and transport phenomena, the potential impact can be predicted to a sufficient degree to allow the ranking of chemicals for further detailed evaluation. This process permits the efficient use of the impact assessment capabilities within government and industry.

Important recent advances in this field have just been published under the editorship of Dr. K.L.E. Kaiser, Lakes Research Branch. The 31-chapter volume deals with acute and sublethal toxicity, bioconcentra-

Lampricide Safety Assessed

Since the use of 3-trifluoromethyl-4-nitrophenol (TFM) as a lampricide began in 1958, the Canada-U.S. Great Lakes Fishery Commission (GLFC) have used more than 1500 tons of this chemical to kill juvenile stages of the sea lamprey in Great Lakes tributaries. In support of this program, the GLFC and the Department of Fisheries and Oceans requested and funded past NWRI research into the persistence and fate of TFM in Great Lakes waters. The NWRI research, led by Dr. J.H. Carey, Chief of the Nutrient-Contaminant Project, Lakes Research Branch, showed that TFM degraded rapidly in the environment. Recently, however, there have been concerns raised about the presence of a previously undetected impurity in the carrier used in the TFM formulation. This impurity is N-methyl formamide (MMF), a toxic chemical with embryotoxic and teratogenic properties. NWRI scientists determined that the concentration of MMF in TFM formulations ranged between 0.0001 and 0.009 percent, which suggests that less than 150 kg have been released over the 20 years of lampricide treatments. From the literature on MMF toxicity, it appears that this level of release is unlikely to cause adverse effects to human and wildlife health.

Reference: Carey, J.H. and J.H. Hart (1987). Concentration of N-methylformamide (MMF) in formulations of lampricide 3-trifluoromethyl-4-nitrophenol (TFM). NWRI Contribution 87-85.

Quality Assurance and Rain Data

NWRI is responsible for ensuring that water chemistry data generated for Environment Canada by any laboratory are of good and comparable quality. A new assignment for the Quality Assurance (QA) Project of the Research and Applications Branch is to evaluate the quality and comparability of data collected in four large precipitation networks over the next two years by the Atmospheric Environment Service (AES), Ontario Ministry of Environment (MOE), the

U.S. Environmental Protection Agency (EPA) and the U.S. Electric Power Research Institute.

The data will be used to validate the Acid Deposition and Oxidant Model which is being developed by AES in cooperation with MOE, the Federal Republic of Germany, and, more recently, the U.S. Electric Power Research Institute. This model and another U.S. one are the most advanced and comprehensive Eulerian models for predicting the long range movement of atmospheric pollutants, but there is a consensus that the model needs to be evaluated by comparison with field observations.

Mirex in St. Lawrence Belugas

The blubber of Beluga whales in the St. Lawrence River estuary contains a variety of toxic organic chemicals. The presence of mirex, a banned insecticide, is noteworthy because there are no known sources in Canada. The St. Lawrence mirex probably came from Lake Ontario, which was contaminated with mirex manufactured in New York State in the 1960s, together with small-scale leakage from U.S. landfill sites in the Niagara frontier. Two transport mechanisms for delivering mirex to the St. Lawrence River estuary have recently been reported by Dr. K. R. Lum, Rivers Research Branch. One mechanism is transport on particles leaving Lake Ontario. The other mechanism, surprisingly enough, is transport in the bodies of migrating adult eels. The analysis showed that almost two-thirds of the annual mirex load (4.6 kg) was transported by eels. The link, however, between the present day input of mirex to the estuary and the accumulated concentrations of mirex in the whales has not yet been established. While mirex export from Lake Ontario is probably decreasing, it will continue at reduced rates for decades, because the rate of permanent burial of mirex into the sediments of Lake Ontario is slow. The fate and effects of contaminants that behave like mirex will be the object of intensive research over the next decade at NWRI.

Reference: Lum, K.R., K.L.E. Kaiser and M.E. Comba (1987). Export of mirex from Lake Ontario to the St. Lawrence estuary. *The Science of the Total Environment* 67: 41-51.

Marketing the Hydraulics Lab

As noted later in the Research Focus section, NWRI maintains within its Research and Application Branch an extensive laboratory to support its research in hydraulics, fluid mechanics, and the hydrologic, geophysics and geological processes of inland waters. The laboratory also provides an instrument calibration service used primarily by Environment Canada's Water Resources Branch and other government agencies. Historically, outside users have taken advantage of the specialized equipment and services, when available, on a cost recovery basis, but the Institute has not actively marketed the laboratory. Recently, however, the Research and Applications Branch hired the consulting firm of Stevenson Kellogg Ernst and Whinney to develop a strategy for maximizing the use of the lab.

In the first phase of their study, the consultants conducted an internal review of the laboratory operations to establish the present marketable capacity. They found that this varies widely depending on the piece of equipment under consideration, but that, in general, enough capacity was available to make marketing efforts worthwhile. In phase two, the consultants interviewed about 40 past and present users to identify the potential market. Consulting engineers appear to be the largest group of users, while the greatest interest was shown in the laboratory's physical modelling capabilities. Phase three of the study drew on these findings and provides NWRI with recommendations for marketing and administration of the available capacity of the Hydraulics Laboratory.

Innovation in Ultra-Trace Analysis

Many contaminants are present in the environment at such low levels that they cannot be measured reliably with conventional methods. Scientists have approached this problem by adding a "preconcentration" step. An extractor apparatus, developed by the late Dr. P.D. Goulden of the Research and Applications Branch, can sample up to several hundred litres of water and greatly concentrate organic compounds found in water at ultra-trace levels. The Goulden

large-sample extractor is currently being used to monitor organic contaminants for the important Niagara River Toxic Monitoring Program.

Recently the extractor was evaluated by the U.S. Environmental Protection Agency (EPA) in a comparative study of preconcentration techniques. Pending the outcome of the study, the EPA may adopt the apparatus for their standard operations in 1988.

STAFF NEWS

International Research Advice

Dr. C.R. Murthy, Lakes Research Branch, recently provided four days of seminars in physical limnology at the Institute of Limnology in Nanjing, China. The seminars, simultaneously translated into Mandarin, covered coastal circulation processes, turbulent diffusion, and numerical modelling, using examples of NWRI applications from the Great Lakes. Thirty limnologists and oceanographers were invited from other

institutes in the Chinese Academy of Sciences. Research advice was also provided on the design of a program on the physics of Lake Tai, a large, shallow lake in the Yangtze River with physical dynamics similar to that of Lake St. Clair and the St. Lawrence riverine lakes downstream of Montreal. Future collaboration between NWRI and the Nanjing Institute is possible.

Dr. S. Beltaos of the Rivers Research Branch recently visited Finland at the invitation of the Finnish Academy of Sciences to give several lectures on river ice research. Dr. Beltaos gave the opening presentation to the Nordic River Ice Meeting, discussing

new developments in North American river ice research. He also lectured on ice jam processes and the hydraulics of ice-covered rivers at the University of Helsinki, the Finnish Geophysical Society, and the Technical University of Helsinki.

A.S.Y. Chau, Research and Applications Branch, was chosen as one of 15 international experts to provide technical advice to the Western Australian Institute of Technology on the development of the Australian national manual, "Analytical Quality Assurance in the Marine Quality Assessment Programme".

Science Exchange with New Zealand

M.E. Fox, an organic chemist in the Lakes Research Branch, recently completed a one-year professional development leave at the Water Quality Centre (WQC) in Hamilton, New Zealand. In exchange, **D. Jensen**, a chemical technologist from WQC spent one year at NWRI learning advanced analytical methods for trace organics and assisting with field and laboratory studies. WQC is an applied research centre of the government of New Zealand with considerable expertise in inorganic, physical, biological, and nutrient studies.

Mr. Fox undertook the task of expanding WQC research in the field of persistent organic contaminants. He examined the fate of the pesticide 2,4,5-T, applied at very high rates to a hill country basin. Negligible losses to streams draining the area were found, even under adverse conditions. The resultant knowledge of chlorophenoxy herbicide breakdown has international applicability in agricultural settings. Other studies resulted in a better method for estimating lake sedimentation rates and new information of organochlorine contamination in one of New Zealand major marine harbors. The presence of chlordane, previously unreported in the New Zealand environment, received wide media coverage and prompted a reassessment of the industrial use of pesticides in New Zealand.

Urban Drainage and UNESCO

The first volume of a UNESCO manual on urban drainage, coauthored by **J. Marsalek**, has recently been published. UNESCO established a working group of eight international experts on urban hydrology to prepare a comprehensive manual on advanced approaches to urban drainage, with special attention to situations in developing countries. Mr. Marsalek, as a member of the editorial board, prepared the final text. The objectives of the manual are to advance understanding of the complex interactions between urban drainage and other facets of urban water resources, and to aid planning, design and implementation of drainage projects.

Reference: Geiger, W.F., J. Marsalek, W.J. Rawls and F.C. Zuidema (1987). Studies and reports in hydrology. No. 43, UNESCO Press, Paris.

Staff Honored

In recognition of his noteworthy contribution to environmental science in the Great Lakes, **Dr. Y.K. Chau** of the Rivers Research Branch has been selected by the International Joint Commission (IJC) for the "Eminent Scientists of the Great Lakes" award. Over 90 of Dr. Chau's publications have been bound in a special volume by the IJC. His influential research in the Great Lakes has been concerned with the fate, pathways, transformation, and speciation of metals and organometallic compounds.

The American Society of Testing and Materials (ASTM), the prestigious international standards association, has granted **B.J. Dutka**, Rivers Research Branch, an award of merit and made him a Fellow of the Society in recognition of his leadership in the establishment of water microbiology working groups within ASTM.

Dr. J.O. Nriagu, Lakes Research Branch, received his Doctor of Science degree in November 1987 from Ibadan University of Nigeria. This degree of merit was awarded to Dr. Nriagu for his significant contributions in the field of environmental geochemistry. Ibadan University is the oldest and most prestigious university of Nigeria. Dr. Nriagu also received the Frank Rigler Award and was invited to give the Frank Rigler Memorial Lecture at the Annual Meeting of the Canadian Society of Limnologists in January 1988. His presentation was on trace metal research in Canadian Freshwaters.

It was with great sadness that we learned of the untimely death of Dr. Peter D. Goulden, November 22, 1987. During his outstanding career, Dr. Goulden made many valuable contributions to analytical chemistry research and his achievements and reputation have been recognized worldwide. Examples of his impact on environmental analytical chemistry include his book "Environmental Pollution Analysis" and his contributions to the Water Quality Branch Analytical Methods Manual and the Analytical Protocol for Monitoring Ambient Water Quality of the Niagara River. Dr. Goulden's recent work on liquid-liquid extraction and his development of the large volume extractor for trace analysis of environmental samples are undoubtedly the highlights of his career. He is survived by his wife Heather, four sons and a daughter.

New Scientist Joins Staff

We welcome **Dr. A. Crowe** to the Groundwater Contamination Project, Rivers Research Branch. Dr. Crowe recently completed his Ph.D. at the University of Alberta, where he developed computer models to simulate the transport of dissolved materials and the geochemical reactions that cause minerals to dissolve or precipitate in deep sedimentary basins. Dr. Crowe's research focus at NWRI will be the development of computer techniques to study groundwater pollution. One of his first priorities will be to model the movement and degradation of toxic chemicals beneath the Gloucester landfill (near Ottawa) and the resulting impact on potable water supplies.

Visiting Scientist from the People's Republic of China

Professor **Tian Shizhong** from the Department of Environmental Science of Wuhan University, China, will be a guest scientist at NWRI until September 1988. He is collaborating with Drs. Y.K. Chau and D.L.S. Liu of the Rivers Research Branch on the degradation of organotin compounds in rivers.

The NWRI Vollenweider Lectureship

We are pleased to announce the establishment of the annual Vollenweider Lectureship in Aquatic Sciences, an honorary award granted annually to an eminent, international freshwater scientist in recognition of his or her global contribution to the advancement of the aquatic sciences.

The lectureship is named in honor of Dr. Richard A. Vollenweider, D.Sc., H.C., Tyler Laureate, Senior Scientist at NWRI, and Professor of Biology at McMaster University, on the occasion of his retirement from the Public Service of Canada late in 1988.

The recipient of the inaugural 1988 Vollenweider Lectureship is Professor Curt Forsberg, Director of the Institute of Limnology, University of Uppsala, Sweden. Professor Forsberg was chosen in recognition of his research achievements in eutrophication abatement, his pioneering work on the recovery of acidified lakes, and his leadership excellence in Scandinavian limnology. He will present the Vollenweider lecture at the Canada Centre for Inland Waters, Burlington, in early June. Visitors are welcome to attend.

MEDIA BACKGROUND

Algoma Research Enhances Case for Accord to Fight Acid Rain (The Sault Star, Sept. 16, 1987)

Research from Algoma lakes is strengthening Canada's argument for an acid-rain accord with the United States.

Lakes can and do recover in a matter of years when emissions are reduced, says Dean Jeffries, a research scientist with the National Water Research Institute in Burlington.

The encouraging results of this NWRI research attracted widespread media attention including The Globe and Mail, the Finnish national newspaper, and U.S. News and World Report. Additional coverage will soon appear in Equinox magazine and in a televised Christian Science Monitor documentary.

The NWRI research team is headed by Dr. D. Jeffries, Rivers Research Branch, in collaboration with several other government agencies. They have found evidence that reduced emissions of sulfate can lead to improved water quality. Records of acidic deposition in Algoma region, north of Sault Ste. Marie, show that sulfate reached a maximum in 1979. This was followed by a steep decline in 1980 and 1981, primarily due to low levels of precipitation, but also due to reduced emissions of sulfur-bearing pollutants in North America during the economic recession of the time. Between 1982 and 1985 sulfate deposition fluctuated between the maximum of 1979 and the minimum of 1980. Mean lake concentrations of hydrogen ion and sulfate declined sharply between 1979 and 1982 but fell only slightly between 1982 and 1985. Correspondingly, mean pH increased by 0.35 units in the first 3-year interval but increased only 0.07 units in the second interval.

Researchers were also encouraged by the return of fish to some of the study lakes over the period. In 1979, 7 of the 54 lakes

sampled had very low pH values (4.6 to 5) and fish were found in only 1 of the 7 lakes. By 1985 the pH in these lakes had increased (ranging between 5.4 to 6.3) and 2 more lakes had developed white sucker populations. It appears that fish migrated from less affected downstream waters into these headwater lakes when pH neared 5.5.

This study adds to a growing body of information from Ontario (Sudbury), Nova Scotia, the U.S., and Sweden that links reductions in sulfate deposition to improved water quality (i.e. reduced acidity). It supports the continuing efforts to negotiate reduction of sulfur emissions throughout North America in order to achieve the needed decrease in deposition.

Oxygen to Resuscitate Hamilton Harbour The Globe and Mail, (July 22, 1987)

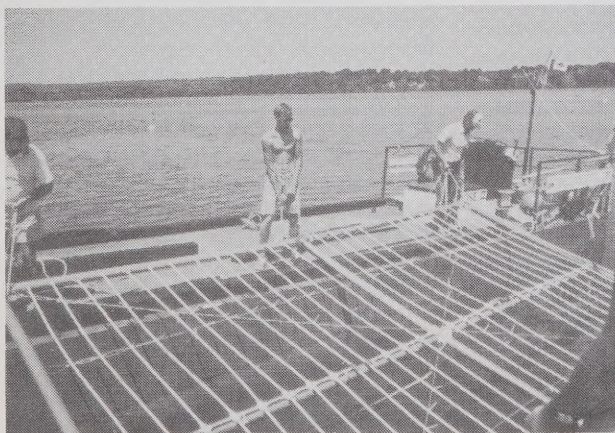
Workmen lowered an artificial lung into Hamilton Harbour yesterday in an effort to breathe life back into some of the most polluted waters in Canada.

This pilot-scale oxygen injection system was designed by Dr. T.P. Murphy of the Lakes Research Branch, with the assistance of engineers from Linde Ltd., a compressed gas supplier. "Artificial lung" is descriptive of the three diffuser grids made up of a

special plastic tubing which is porous to oxygen under pressure. The grids were placed near the bottom in the western end of Hamilton Harbour. The oxygen was supplied by a liquid oxygen tank, similar to installations seen outside hospitals.

The pilot-scale test was designed to see if the efficiency of dissolving oxygen in the harbour could approach that seen in the laboratory. The efficiency, which approached 90 percent in the harbour, has a direct effect on the economics of the application of this technique. Such high efficiencies bode well for the practicality of the method.

Although data analysis is incomplete, initial observations at the pilot site last summer indicate the area around the diffusers also becomes a desirable fish habitat. For instance, cormorants were observed feeding on emerald shiners schooling near the diffusers. Treatment of the whole harbour with oxygen is one of the several restoration techniques being evaluated by a multi-agency group currently developing a remedial action plan for the harbour.



A device for diffusing oxygen is lowered into Hamilton Harbour

The Contaminants Project

It has been estimated that there are over 70 000 industrial chemicals in common use worldwide. Some of these pose a threat to human health or the environment (e.g. lead, mercury, chlorofluorocarbons), but many have not been subjected to proper hazard assessment. In addition, there are many other potentially harmful chemicals released to the environment, such as products of incomplete combustion (e.g. polynuclear aromatic hydrocarbons and some dioxins) and pesticides, about 500 of which are registered for use in Canada. The broad objective of the Contaminants Project within the Rivers Research Branch is to develop new knowledge for use by Environment Canada in assessing the hazard posed by toxic chemicals released to Canadian rivers.

Hazard to organisms in water or sediment is a function of the concentration, toxicity and persistence of the toxic chemical. Past research in the project has dealt mainly with the chemical aspects of hazard determination—from the development of analytical methods to determinations of occurrence and persistence in aquatic environments. More recently, research has focused on the use of biological indicators of chemical contamination. Future research will concentrate on the determination of the effects of toxic substances on aquatic communities and ecosystems.

Priority topics for research are chosen in response to a variety of concerns. There may be knowledge gaps in the literature on a particular chemical or process, e.g. mobilization of metals through methylation. Chemicals may already be identified in priority lists for risk assessment (e.g. the Pest Control Products Act), or there may be regional concerns about the heavy use of a chemical in a particular area.

An example of the environmental value of contaminant research is our work on tributyltin (TBT). TBT is an antifouling agent, perhaps the most acutely toxic chemical to aquatic organisms which has ever been deliberately introduced to water. In 1979, Environment Canada placed organotin compounds on the Environmental Contaminants Act, Category III list, which meant that further information was required on

occurrence, persistence and toxicity before environmental and human health hazard assessments could be made. Work done at NWRI was the first anywhere in the world on the occurrence of TBT in water, sediment and fish, and on the chemical and biological degradation and persistence of TBT in water and sediments. TBT was found to be moderately persistent in Canadian waters and present in many locations in Canada at concentrations which could cause chronic toxic effects in sensitive organisms. These results were communicated to Agriculture Canada, which administers the Pest Control Products Act. On October 26, 1987, Agriculture Canada gave public notice of a limited ban on the use of TBT-containing antifouling paints. This ban, plus restrictions on the use of TBT in aquaculture, will help Canada avoid the unfortunate experience of smaller countries with large concentrations of TBT-painted boats close to vulnerable fisheries.

The current studies which comprise the project are focused on resolving selected knowledge gaps concerning the occurrence, persistence, and toxicity of priority contaminants. Some highlights follow.

Concentration (Occurrence)

Tetraethyllead is a toxic chemical used primarily as an antiknock additive in gasoline. In Canada, tetraethyllead has been produced at two locations; one on the St. Clair River downstream of Sarnia, and the other (where production ceased in 1986) on the St. Lawrence River at Maitland. Methods of analysis have been developed for tetraethyllead (and its dealkylated products) in water, sediment and fish, and the occurrence of these compounds downstream of the two plants has been documented. Triethyllead, in particular, is very toxic to fish. This work is being extended to investigate the biological availability of the alkyllead compounds in water and sediment using clams as the indicator organism.

Work has recently started on the determination of the aquatic occurrence, persistence and fate of pesticides and industrial chemicals (mainly dyestuffs and aromatic amines) in the Yamaska River in Quebec. The Yamaska River is in the Eastern Townships, the heart of Canada's textile

industry, and receives about a quarter of all pesticides used in agriculture in Quebec. The first stage of this study will determine the occurrence of toxic chemicals in water, sediment and fish.

The Yamaska is also the site for research on biomonitoring techniques to assess bioaccumulation and toxic effects of contaminants. Mussels are known to be excellent biomonitors from the standpoint of bioaccumulation, but their considerable potential for use in ecotoxicology remains largely untapped. Mussels are particularly suitable for both types of monitoring since they concentrate and retain a wide range of contaminants, are widely distributed, are easy to identify and age, and are amenable to experimental caging studies. The suitability of mussels as biomonitors for pesticides in the Yamaska River is currently being evaluated.

Persistence

An important pathway of degradation of many organic contaminants in aquatic ecosystems is microbial decomposition. The techniques used in evaluating the biodegradability of organic substrates vary greatly in effectiveness because of complicating phenomena in pure and mixed cultures, such as co-metabolism and the induction of different routes of enzymatic degradation through changes in such factors as nutrient status, temperature, pH, and oxidation-reduction potential. A so-called fermentor technique developed earlier at NWRI has proven to be a useful tool in assessing the biodegradation potential of organic chemicals in aquatic ecosystems. Presently the biodegradation of pentachlorophenol and other phenols is being studied, as well as tetraethyllead. This work will be shortly extended for use in assessments of biodegradation potential in laboratory-scale, model streams.

The persistence and fate of the pyrethroid insecticide, deltamethrin, sprayed on a stream and pond in Prince Edward Island, is also being studied. Preliminary results indicate very rapid disappearance from water, with half-lives of about five minutes for the surface microlayer and one hour for subsurface water. Non-toxic stereoisomers of deltamethrin have been identified, as well as products of hydrolysis and oxidation.

The Contaminants Project (continued)

Toxicity

The "health" of benthic invertebrate communities may be an effective indicator of contamination in rivers. An assessment is currently being made of the benthic invertebrate communities in several reaches of the Yamaska River for correlation with chemical analyses. Benthic community surveys do, however, lack the specificity afforded by the study of a species' biochemical response to toxicants. For example, the free amino acid content of an organism is thought to vary with degree of stress. Amino acid concentrations are thus being measured in invertebrates at several sites in the Yamaska River in an effort to determine correlations between biochemically indicated stress and chemical contamination at a particular location. Further work is planned on the development of methods to assess the toxicity of pesticides to stream invertebrates and to determine the effects of particulate and dissolved organic matter. This will include the development of bioassay techniques for filter-feeding organisms which live in fast-flowing water, and may include the construction of artificial stream microcosms or mesocosms for more detailed work on the effects of agricultural runoff on rivers and streams.

Project Chief: R.J. Maguire

**Study leaders: Y.K. Chau, K.E. Day,
D.L.S. Liu, K.R. Lum, J.L. Metcalfe.**

Recent Publications

Maguire, R.J. (1987). Review of environmental aspects of tributyltin. *Appl. Organometal. Chem.* 1: 475-498.

Chau, Y.K., P.T.S. Wong, G.A. Bengert and J. Wasslen (1987). Bioconcentration of alkyllead compounds by clams. In: *Heavy Metals in the Environment*, S.E. Lindberg and I.C. Hutchinson, eds, C.E.P. Consultants, pp. 166-168.

Chau, Y.K., P.T.S. Wong, C.A. Mojesky and A.J. Carty (1987). Transmethylation of metals in aquatic systems. *Appl. Organometal. Chem.* 1: 235-239.

Metcalfe, J.L. (1988). Aquatic leeches (*Hirudinea*) as a biological screening tool for detecting organic contaminants in the environment. *Proc. of the North American Benthological Society Annual Meeting*, Orono, ME, USA, June 1987 (in press).

Liu, D.L.S. and K. Thomson (1987). Microbial activity and biodegradation potential in Lake Ontario sediment. In: *Proc. of the 20th Annual Conference on Trace Substances in Environmental Health*, 1986, Columbia, MO, USA, ed D.D. Hemphill, pp. 466-472.

The Hydraulics Project

The physical dynamics of water and its interaction with air, sediments, shores, and man-made structures are the focus of the Hydraulics Project, Research and Applications Branch. Research studies on wave mechanics, river flow and sediment transport provide new scientific knowledge for use by water resource managers and engineers.

A current focus of the project is a major study on wave mechanics in collaboration with scientists from Finland and several American institutions (the Woods Hole Oceanographic Institution, U.S. Naval Research Laboratory, U.S. Naval Environmental Prediction Research Facility, and the Finnish Institute of Marine Research). This team, led by Dr. M. A. Donelan, has collected and analysed three years of field measurements on the behavior, dynamics and effects of deep-water wave breaking. The data, when interpretation is complete, will lead to improved predictions of the dispersion of pollution spills in lakes and oceans, assist in design and operation of offshore petroleum exploration equipment, and help to improve the accuracy of weather and climate predictions.



WAVES platform, fully operational, November 1987

The experimental site for the waves research is NWRI's unique research tower located in 12 m of water in Lake Ontario, one km offshore of Hamilton. An array of over 50 environmental instruments are deployed on the tower and controlled by means of computer from an adjacent onshore trailer. Researchers thus can conduct experiments in the most violent of storms. The facility and equipment have overcome many of the serious technical difficulties that have hindered this type of research in the past. The equipment includes various water current meters operating on principles of sound transmission, light frequency shifting (laser Doppler), drag forces on tiny spheres, and the cooling of small, heated rods. With the field work completed, NWRI and Woods Hole scientists now have a comprehensive data set to allow them to make improvements to numerical wave models. They will also be

able to understand better the distribution of turbulent energy in the upper layers of oceans. With this information, models can be developed to predict dispersal of slightly buoyant pollutants.

NWRI and the U.S. research teams working on the project has been examining the response of microwave radars to small, wind-generated surface ripples, called "cats-paws" by sailors. This type of radar is already in place on satellites to observe surface ripples from space. The experiments conducted at the research tower will provide scientists with the information needed to use the satellite radar data to infer winds over oceans. This is vital to more accurate weather and climate prediction. At present the most critical impediment to improved long-term forecasting is the lack of information on daily weather conditions over vast reaches of the world's oceans.

The results of this joint study have been so encouraging that an even larger effort has recently been announced. Dr. Donelan has been named coordinating chairman for a new \$4.5 million international research project on surface wave dynamics. The project, funded by the U.S. Office of Naval Research, involves 21 investigators from 16 research organizations worldwide. Expected

theoretical and instrumentation advancements from this program will improve our understanding of wind-driven pollutant mixing phenomena and develop better wave forecasting. Data from wave reflectivity sensors on a new satellite to be launched in 1990 will be validated with oceanographic data collected by traditional means. Satellite sensors will then be able to provide, for the first time, comprehensive global information on wave-induced movements in large lakes and oceans.

In addition to wave research, the Hydraulics Project includes research in the areas of coastal and fluvial engineering. Current studies in coastal engineering are addressing the resuspension of cohesive sediments by waves, the development of hindcasting models of wave climates and shoreline evolution, and the interaction between waves and man-made structures. The fluvial

The Hydraulics Project (continued)

engineering program is directed towards improving our understanding of fluid mechanics and sediment transport in rivers, flow-structure interaction, and innovations in river monitoring.

Technical staff within the project also operate NWRI's large Hydraulics Laboratory and provide specialized support to professional laboratory users and to cost-recovery projects. The National Calibration Service calibrates and repairs current meters, and operates the towing tank facility for NWRI, the Water Resources Branch of Inland Waters Directorate, and private sector users.

Project Chief: M.G. Skafel

Study leaders: M.A. Donelan,

C.T. Bishop, P. Engel, W.B. Taylor.

Recent Publications

Bishop, C.T. (1987). Great Lakes water levels: A review for coastal engineering design. Prepared for the Marine Directorate, Public Works Canada. NWRI Contribution No. 87-18.

Bishop, C.T. and M.A. Donelan (1987). Measuring waves with pressure transducers. *Coastal Engineering* 11: 309-328.

Bishop, C.T. (1987). Wave attenuation by rubble-lined channel walls. *Canadian Journal of Civil Engineering*, Vol. 14, No. 4.

Coakley, J.P., M.G. Skafel, R. Davidson-Amott, A.J. Zeman and N.A. Rukavina (1988). Computer simulation of nearshore zone profile evolution in cohesive materials. NWRI Contribution 88-25.

Donelan, M.A. and K.K. Kahma (1986). Observations of velocities beneath wind-driven waves. *Proc. of the International Workshop of Wave Hindcasting and Forecasting*, Halifax, N.S., Sept. 23-26. Environmental Studies Revolving Funds, Report Series No. 065, Ottawa, pp. 243-252.

Kahma, K.K. and M.A. Donelan (1988). A laboratory study of the minimum wind speed for wind wave generation. *J. Fluid Mech.* (in press).

Krishnappen, B.G. and P. Engel (1987). Evaluation of sediment transport and friction factor equation using MOBED. *Proc. of the ASCE 1987 National Conference on Hydraulic Engineering*, Williamsburg, Virginia.

Merzi, N. and M.A. Donelan (1987). Transfer at the air-water interface. NWRI Contribution 87-157.

Skafel, M.G. and M.A. Donelan (1987). Settling and resuspension of fine sediments by waves. NWRI Contribution 87-158.

Tsanis, I.K. and M.A. Donelan (1987). The "WAVES" program on the NWRI Research Tower. NWRI Contribution 87-65.

Venkatesh, S., M.A. Donelan, H. Graber, P. Liu, D. Schwab and M.G. Skafel (1988). Finite depth wind waves — a preliminary analysis of data from a field study on Lake St. Clair. NWRI Contribution 87-153.

COMING EVENTS

August 15-18, 1988: Trace Metals in Lakes. This international conference will be held at NWRI (Canada Centre for Inland Waters, Burlington, Ontario). The main topics discussed will be the extent of trace metal contamination of lake ecosystems, the effect of lake acidification on cycling and bioavailability of metals, and the similarities and differences of trace metal and nutrient cycles in marine and lake ecosystems. A short course on clean-lab techniques is being organized to complement the conference. Deadline for submission of the abstracts is March 31, 1988. The proceedings will be published in "Science of the Total Environment". For more information, contact Drs. J.O. Nriagu or K. Lum, (416)336-4784/4617.

August 29-September 2, 1988: First Biennial Water Quality Symposium: Microbiological Aspects. This major symposium will be held in Banff, Alberta and will focus on microbiological contamination and hazards in water and on methods to assess and remove these problems. For more information, contact the organizers, B.J. Dutka or Dr. D.R.S. Liu, (416) 336-4576/4923.

October 10-14, 1988: The Fate and Effects of Toxic Chemicals in Large Rivers and their Estuaries. This international symposium is being organized jointly by NWRI and Institut National de la Recherche Scientifique-Eau. It will be held in Quebec City. The focus of the conference will be on the transport mechanisms, partitioning, fate and effects of toxic chemicals as detected by ecotoxicological methods. Several keynote papers from specialists in western Europe and the U.S. will be presented. Deadline for submission of abstracts is March 31, 1988. For more information, contact Dr. R.J. Allan, (416) 336-4678.

About NWRI

Environment Canada's National Water Research Institute (NWRI) conducts a national program of original research and development in the aquatic sciences, in partnership with the international freshwater science community. The twin goals of the Institute are to advance scientific understanding of national and international water issues important to Canada and to develop knowledge and authoritative expertise on these issues that can be used by Environment Canada to influence decisions affecting the wise management of Canada's water resources.

Research at NWRI is conducted within multidisciplinary projects, each focusing on a priority issue. Projects are grouped within three branches, the Lakes Research Branch, the Rivers Research Branch, and the Research and Applications Branch. Current long-term research priorities include: toxic chemicals in the Great Lakes and the St. Lawrence River; exchange of toxic contaminants between air, water, sediments, and biota; groundwater contamination; pesticide contamination in rivers; acid rain; lake rehabilitation; and aquatic monitoring, ecotoxicology, and risk prediction methodologies.

NWRI Digest

The NWRI Digest is the quarterly public newsletter of the National Water Research Institute, Conservation and Protection, Environment Canada. Suggestions, comments and further enquiries concerning newsletter items are welcomed. Please write to the Editor, NWRI Digest, National Water Research Institute, P.O. Box 5050, Burlington, Ontario, Canada L7R 4A6.

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NWRI and the 1987 Great Lakes Water Quality Agreement

In November 1987, a new Protocol to the Great Lakes Water Quality Agreement (GLWQA) between Canada and the United States was signed at the International Joint Commission Biennial Meeting in Toledo, Ohio. The Protocol includes several new or revised Annexes which will require additional research programs before they can be implemented. Increased scientific knowledge is necessary to control toxic chemicals, restore Areas of Concern (AOCs) and develop lakewide management plans for toxic chemicals.

A new Research and Development Annex, Annex 17, commits the two

countries to a comprehensive ecosystem approach to pollution issues in the Great Lakes. Two other new Annexes to the Protocol necessitate expanded research on the role and rehabilitation of contaminated sediments (Annex 14) and on the atmospheric deposition of toxic chemicals to, and their subsequent release from, the Great Lakes (Annex 15). Annex 2 was also completely redefined to focus on remediation plans needed to restore Great Lakes AOCs and to develop lakewide management plans for toxic chemicals. These activities will require extensive research before protocols can be developed to assess the degree of pollution or recovery of AOCs; to quantify non-point sources of chemicals; to resolve ecosystem interactions so that successful and cost effective remedial measures can be developed; and to test *in situ* remedial options to deal with the contaminated sediments found in 41 of the 42 AOCs. NWRI scientists made major contributions to the earliest drafts of some Annexes including Annexes 14, 15, 16 (on Pollution from Contaminated Groundwater) and 17.

Recently, the research program in the Lakes Research Branch (LRB) of NWRI was refocused to respond to the next generation of limnological problems. LRB, the focal point of NWRI research on the Great Lakes, is now organized into five broad interdisciplinary projects. These address the problems associated with: the role of contaminated

sediments in toxic chemical accumulation by biota and how to deal with such sediments; the importance of atmospheric deposition of toxic chemicals in lakewide mass balances and how to factor this into programs controlling other sources; the interactions between connecting channels, nearshore areas and open lake waters; the processes and procedures for restoring severely polluted sites, such as the AOCs; and the relationships between nutrient inputs or trophic state of lakes and the fate and effect of toxic contaminants. This latter project on nutrient-contaminant interactions represents a more comprehensive ecosystem approach to lake pollution because nutrients and contaminants and their interactions need to be considered simultaneously. Better understanding in all of these areas is essential for setting multi-chemical ecosystem objectives, based on *in situ* ecotoxicological tests (rather than dissolved concentrations of single chemicals), and for developing useful lake management plans. In addition, research on agricultural pesticides, urban runoff and remediation of groundwater pollution has been consolidated within the Rivers Research Branch. Thus, NWRI has embarked on projects which will have a major role to play in meeting the goals set forth in the new Protocol to the GLWQA.

Dr. R.J. Allan
Director
Lakes Research Branch

INSIDE

- UV Sterilization of Wastewater
- Lake Erie, Lake Ontario Research Volumes
- P.E.I. Groundwater Contamination
- Bio-assessment Workshop
- Global Trace Metal Pollution Assessed
- Collaboration with ILEC
- Promoting Analytical Quality Assurance
- Hydrocarbons in the Mackenzie River
- New Analytical Methods
- Hamilton Harbour "Remedial Action Plan"
- CCIW Open House '88
- The Air-Water Interactions Project
- The Ecotoxicology Project



RESEARCH NEWS

Lake Erie, Lake Ontario Research Volumes

Results from two intensive, multidisciplinary research programs on Lakes Erie and Ontario, undertaken by NWRI in collaboration with several universities and U.S. government agencies, were recently released as special journal volumes. Both identify, quantify and interpret the limnological effects of the large-scale phosphorus abatement programs instituted by Canada and the U.S. in the 1970s to reduce eutrophication.

In the Lake Erie study, the most biologically productive of the Great Lakes, major efforts were made to characterize and model the changes in hypolimnetic oxygen depletion in the lake in response to phosphorus reductions. Weather conditions during the stratified period, together with a strong temporal lag in sediment oxygen demand, appear to have obscured the long-term effects of declining phosphorus. Computer simulation models were developed and used to validate these conclusions. In general, the study reflects the major advances made in the last decade in understanding the processes controlling the Lake Erie ecosystem.

The Lake Ontario study focused on the effects that phosphorus reductions have

had on primary and secondary production in the lake. Long-term field data on phosphorus and phytoplankton levels, combined with physiological measurements, indicated that short-lived events in the lake, such as the settling of lipid-rich diatoms, were important to overall biogeochemical cycling and fishery production. Such events occur shortly after the onset of thermal stratification in spring and can provide much of the utilizable food to the benthic component of the ecosystem which supports the fishery. Later in the season most of the primary production is recycled into other biota or converted to CO₂, primarily through the actions of heterotrophic nanoplankton. This poorly understood group of microorganisms comprises up to half of the lake's biota in the size range of 2-20 microns. Current computer models that are used to predict the effects of decreased nutrient loadings on the fate and effects of contaminants in the Great Lakes will need modification to take into account the role of nanoplankton on these processes.

Another major observation in this study was unexpected. The decrease in lake phosphorus concentrations that was expected to follow the reduction in lake

loadings was only partly realized. Phosphorus concentrations during spring overturn have declined year by year. However, summer epilimnion concentrations have not and remain higher than the hypolimnetic values. This is an unusual response and further work is required to identify the processes unique to Lake Ontario which produced it.

The authors of both volumes repeatedly point out the need for more complete ecosystem understanding if we are to better predict the effects of controlling even one environmental variable (phosphorus loading). As Lean *et al.* (1987) note for these lakes, the "limits of use and abuse are set by biogeochemical processes".

References

- Boyce, F.M., M.N. Charlton, D. Rathke, C.H. Mortimer and J.R. Bennett (1987). Lake Erie research: Recent results, remaining gaps. Lake Erie Binational Study 1979-1980, J. Great Lakes Res. **13**, No. 4: 826-840 (30 papers).
- Lean, D.R.S., H.J. Fricker, M.N. Charlton, R.L. Cuhel and F.R. Pick (1987). The Lake Ontario Life Support System. Canadian J. Fish. Aq. Sci. **44**, No. 12: 2230-2240 (22 papers).

UV Sterilization of Wastewater

A novel ultraviolet (UV) disinfection process was recently chosen over conventional chlorination for use in a new sewage treatment plant in Quebec City. This decision is the culmination of ten years of effort by Trojan Technologies of London, Ontario, to take an idea developed at NWRI to a commercially successful application. In 1976, Drs. J.H. Carey and B.G. Oliver demonstrated for the first time the efficiency of

UV sterilization of particulate matter characteristic of secondary sewage effluents, reporting that a 99 percent destruction of target organisms could be achieved at fairly low doses of UV. Subsequent scientific consultations with the company and the National Research Council led to a two-year field trial of the technology at Tillsonburg, Ontario, where the superior efficiency, practicality and economics of the UV system

over conventional chlorination was proven. This is an example of the kind of successful technology transfer that is promoted as an adjunct to NWRI's mission-oriented research.

Reference: Oliver, B.G. and J.H. Carey (1976). Ultraviolet disinfection: an alternative to chlorination. J. Water Pollut. Contr. Fed. **48**: 2619-2624.

Bio-assessment Workshop

A successful Environment Canada workshop on "Biology in the New Regulatory Framework for Aquatic Protection" was held in Alliston, Ontario, in late April. The workshop, organized and chaired by Dr. E. Ongley, Director of NWRI's Rivers Research Branch, brought together federal and provincial regulators, industry representatives, private sector consultants and the scientific community to examine the implications of the expanded use of biological criteria in aquatic regulation. Following overview sessions on new and existing legislation (Canadian Environmental Protection Act, the Ontario Municipal and Industrial Strategy Abatement, and the Pest Control Products Act) and on the science of biological effects assessment, discussion groups examined a number of specific issues.

Consensus was reached on several recommendations. Canadian regulatory criteria and test protocols should be developed in response to well defined environmental objectives agreed upon through a consultative process. Standardized bioassays, consisting of tiered batteries of tests using both laboratory and ambient organisms, should be applied to the assessment of wastewaters and leachates. The federal government should continue to provide strong leadership in research and development (R&D), but participation by universities in R&D should be enhanced. Regulatory criteria and test protocols should be developed within Canada, with due regard for international experiences and existing protocols, and the federal government should be responsible for technology transfer to the private sector. Involvement by the

private sector in monitoring, data evaluation and, to a lesser extent, R&D, should be increased. To ensure uniformity and accuracy, the government should keep leadership in national quality assurance/quality control and be responsible for laboratory certification in biological and chemical testing.

The discussion summaries and recommendations to be published in the Workshop Proceedings will provide policy makers with a range of perspectives on the emerging utility of toxicity testing and bio-effects monitoring in environmental regulation.

Global Trace Metal Pollution Assessed

Dr. J.O. Nriagu, Lakes Research Branch, and Dr. Jozef Pacyna of the Norwegian Institute for Air Pollution Research have just published a major review article in *Nature* in which they present the first quantitative worldwide assessment of the annual input of trace metals into air, soil and water. Global data for 13 trace metals in freshwater, oceans and soils are analyzed for the first time, and an analysis of atmospheric emissions, first reported by Dr. Nriagu in 1975, was updated.

Soil contamination results mainly from disposal of coal combustion residues and general wastage of commercial products on land. Wastes associated with animal husbandry are also significant.

Although background levels of trace metals in soils are naturally high, the retention capacity of many soils for future inputs of trace metals may be limited and could quickly be exceeded in some cases, causing soil fertility problems.

Emissions of copper, lead, zinc and cadmium have decreased in the last 15 years, although anthropogenic sources of lead are still 17 times higher than natural sources to the atmosphere. For most trace metals, the releases to aquatic ecosystems are higher than atmospheric emissions. If even a quarter of the airborne metals find their way first to freshwater systems, the potential extent and severity of contamination is considerable.

The authors also point out that a number of processes occur in freshwater that can keep concentrations low in the water, thus concealing a potential contaminant burden which could suddenly become critical. The global toxicity of trace metals released each year is now estimated by the authors to exceed the combined toxicity of all the radioactive and organic wastes produced annually.

Reference: Nriagu, J.O. and J.M. Pacyna (1988). Worldwide contamination of the air, water and soils by trace metals— Quantitative Assessment. *Nature* **333** (6168): 134-139.

P.E.I. Groundwater Contamination

Residues of aldicarb, an extremely toxic carbamate insecticide, have been detected in routine analyses of drinking water from wells in Prince Edward Island (P.E.I.). Studies currently being conducted by the Groundwater Project of the Rivers Research Branch at two field sites in P.E.I. are designed to better understand the subsurface migration and fate of aldicarb in relation to its application.

Although aldicarb oxidizes rapidly to the aldicarb sulfoxide and aldicarb sulfone, these by-products are equally toxic. They degrade, however, to less toxic forms by hydrolysis and dehydration. Rates of degradation are controlled primarily by temperature and pH, with persistence of the toxic species occurring in cold groundwater with a pH

Continued on page 4



Obtaining groundwater for chemical analysis.

Continued from page 3

range of 5-6. The NWRI field studies have found that a correlation exists between high concentrations of nitrate and high concentrations of aldicarb, indicating a possible link between aldicarb persistence and the degradation of ammonia fertilizer used on the potato fields. Nitrification (the oxidation of ammonium) produces protons as well as nitrate, thus lowering the pH of the groundwater. The groundwater in the sandstone aquifer is highly oxygenated (5-10 mg/L), suggesting ideal conditions

for rapid nitrification in the unsaturated zone. The decrease in pH due to nitrification of ammonia and the low temperature of the groundwater (10° C) in P.E.I. present ideal conditions for aldicarb persistence. Work is continuing to quantify how nitrification affects aldicarb degradation and to develop modified agricultural practices to minimize persistence.

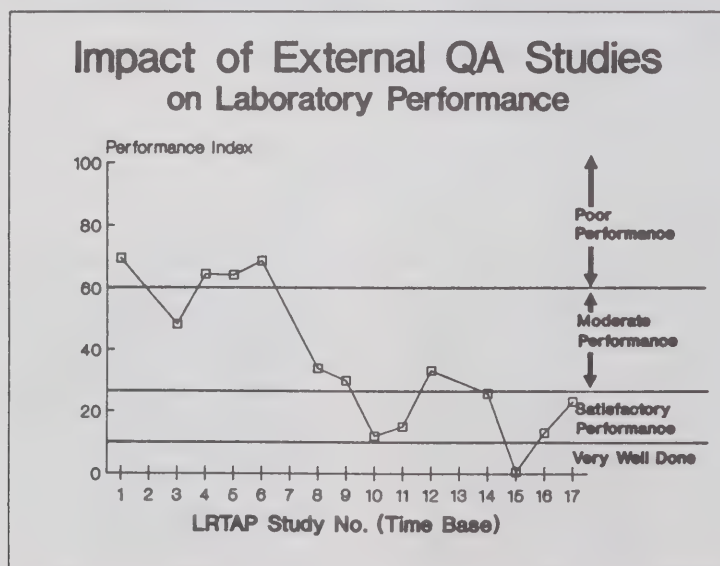
Reference: Priddle, N.W., R.E. Jackson, A.S. Crowe and J.P. Mutch (1988). Aldicarb and nitrogen residues in a sandstone aquifer. NWRI Contribution No. 88-02.

Promoting Analytical Quality Assurance

The Quality Assurance Project of NWRI is responsible for design, management and promotion of aquatic interlaboratory quality assurance (QA) programs. To support these goals, a national QA management workshop was recently held in Ottawa in conjunction with the Water Quality Branch (WQB) of Inland Waters Directorate.

Dr. J. Lawrence, Director, Research and Applications Branch, opened the workshop with an overview of the benefits of QA from the management perspective. A.S.Y. Chau discussed the necessities and pitfalls of designing and executing a QA program, drawing on his recent experience as Chairman for the Upper Great Lakes Connecting Channel Surveillance (UGLCCS) QA Project. This was a particularly effective international multi-agency project,

involving several government agencies from Canada and the United States. K.I. Aspila then discussed the benefits of QA to the performance of individual laboratories, citing evidence from QA studies for the Long Range Transport of Airborne Pollutants program. He also demonstrated a new data management program developed at NWRI that records and graphs the performance of laboratories participating in QA round-robins. In the graph below, a high performance index is indicative of a high frequency of biased parameters and/or poor precision within a study. The time base for this figure is 1982 to 1988, during which the performance of this example laboratory improved from poor to good. Other presentations at the workshop were given by H. Agemian of the National Water Quality Laboratory and Dr. J. Gaskin of the WQB, Ottawa. The sessions were videotaped and copies will be distributed to the Regional Offices of Environment Canada and other interested organizations.



Hydrocarbons in the Mackenzie River

The lower Mackenzie River, the largest northward-flowing river in North America, has been the site of a number of recent studies of hydrocarbon pollution. Initial scientific assessments were prompted by concerns for the state of the Mackenzie River fishery and were focused on the refinery development at Norman Wells just south of the Arctic Circle. In an allied baseline study, NWRI researchers have examined, and recently reported on, the downstream pattern of two groups of hydrocarbons—normal alkanes and polyaromatic hydrocarbons (PAHs)—associated both with water and suspended sediments. By comparing chemical “fingerprints” of water and sediment during spring discharge with those of late summer, low-flow conditions, they found similarities in the hydrocarbons above and below Norman Wells. This suggested that natural oil seeps (well known in the Mackenzie River) are the source of these hydrocarbons rather than refinery effluents. Moreover, PAHs were barely detectable in summer, but found in higher concentrations and differing composition in spring discharges. It appears that PAHs originating from combustion may be distributed by atmosphere processes, deposited during the winter on snow and then released to the river during spring snowmelt. Generally, the concentration and composition of measured hydrocarbons varied along the 1300 km of river sampled, presumably reflecting variable inputs and losses of both pollutants and suspended sediments.

These results have important implications for sampling procedures in remote northern rivers. Currently, most monitoring programs sample only water, but the Mackenzie study has shown that the contaminant load carried in suspended sediments can sometimes exceed 70 percent of the total; both water and sediment must be taken into account when calculating organic loadings to rivers, as must seasonal variations in river flow and the concentrations of suspended sediments.

Reference: Nagy, E., E.D. Ongley and J.H. Carey (1988). Final report on hydrocarbon pathways in the Mackenzie River. NWRI Contribution No. 88-81.

New Analytical Methods

New and improved analytical methods are continually being developed by scientists in the Analytical Chemistry Project, Research and Applications Branch. These methods are required to address specific needs of water pollution research and monitoring programs.

Trace metals are monitored in the environment because of their potential toxicity. Cadmium, for example, is a priority pollutant of concern which has received considerable attention. Dr. V. Cheam and a visiting Chinese scientist, Dr. E Xue Li, have developed a sensitive, automated, cost-effective ion chromatographic method for the simultaneous analysis of cadmium,

cobalt and manganese in water samples at ultra-trace levels. The method is completely automated with on-line concentration of the metal ions. It is relatively inexpensive compared to existing techniques.

Chlorophenols have potential biocidal properties and are heavily used as wood preservatives in the lumber industry. Dr. H.B. Lee has developed a method for the simultaneous analysis of 20 chlorophenols and their corresponding chloroanisolet metabolites at trace levels in animal tissues. A parallel method for the determination of ultra-trace levels of these chloroanisolet in water and sediment samples has also been developed. These methods are

being used in ongoing studies of the transport and fate of chlorophenols and on the environmental hazards of chloroanisolet in British Columbia and elsewhere.

References

Cheam, V. and E Xue Li (1988). Determination of low level Cd^{2+} , Co^{2+} and Mn^{2+} in water by ion chromatography. NWRI Contribution No. 88-65.

Lee, H.B. (1987). Determination of 21 chloroanisolet in water and sediment samples. J. Assoc. Offic. Anal. Chem., Vol. 91 (in press); NWRI Contribution No. 87-69.

Lee, H.B. (1988). Analysis of chlorophenols and chloroanisolet in fish tissues. NWRI Contribution (in press).

Hamilton Harbour "Remedial Action Plan"

The scientific Writing Team for the Hamilton Harbour Remedial Action Plan, chaired by Dr. G.K. Rodgers of NWRI, recently released a planning report entitled "Remedial Action Plan for Hamilton Harbour: Goals, Problems and Options". Remedial Action Plans (RAPs) are to be developed for the 42 "Areas of Concern" in the Great Lakes so designated by the International Joint Commission. The document describes current problems in the harbour and discusses management options to enhance both the present uses of the harbour as well as to restore water quality and shoreline habitat for uses that were lost or not exercised in the past.

During the summer, the general public and a formal Stakeholder Group (who

represent federal, provincial and local governments, industries, conservation authorities and sports fishing, and other recreational groups) will have an opportunity to review the options. Recommendations regarding implementation and scheduling of the final plan will be made by the Stakeholder Group in September. The Hamilton Harbour Writing Team will then prepare a formal Remedial Action Plan for submission to the Canada-Ontario Agreement Review Board and the International Joint Commission.

NWRI scientists have conducted a broad range of research studies in direct support of the Hamilton Harbour RAPs and have made significant contributions to data analysis, interpre-

tation and preparation of the document. One encouraging conclusion to emerge from the analysis is that the harbour has responded positively to the pollution control measures put in place over the last ten years by municipalities and industries. Few important water quality objectives were exceeded in 1987. Many fish species were found to be no more contaminated than those in Lake Ontario and were edible according to provincial guidelines. Oxygen depletion in the hypolimnion and low water clarity continue, however, to limit a full range of water uses.

Collaboration with ILEC

NWRI has been named by the International Lake Environment Committee (ILEC) as the Canadian coordinating centre for compilation and input of Canadian lake data to the joint ILEC/UNEP "Survey of the State of World Lakes". ILEC, a non-governmental lake management organization based in Japan, is presently extending its 1983 "Data Book of World Lake

Environments" to cover siltation, acidification and toxic chemical contamination as well as eutrophication. In addition, a less comprehensive "Catalogue of World Lakes" is being prepared for the 96 Canadian lakes larger than 500 square kilometers. Lakes Research Branch, with ILEC funding, will be liaising with federal, provincial and university scientists over the next year

to compile existing data according to ILEC protocols. At present, only data from the Laurentian Great Lakes and a few other important lakes in Canada have been summarized for the "Data Book". By the time the project is completed, the number of lakes included could be more than 20.

STAFF NEWS

IJC Science Advisory Board

Dr. J. Barica, Senior Limnologist in Lakes Research Branch, has recently been appointed to the Science Advisory Board (SAB) of the International Joint Commission (IJC) for a three-year term. Dr. Barica replaces **Dr. R.J. Allan**, Director, Lakes Research Branch, therefore maintaining continuity in terms of advice and influence to the SAB from NWRI. Dr. Barica has expertise in the limnology of hyper-eutrophic systems (currently important to restoration of Areas of Concern) and in the management of multidisciplinary research programs.

During his three-year appointment, Dr. Allan promoted the need for research on contaminated sediments and made the SAB presentation on this topic to the 1986 IJC Biennial Meeting in Kingston, Ontario. He also urged expanded research on processes affecting the exchange of toxic chemicals at the surface of lakes. To this end, he represented the SAB on the Planning Committee for the 1986 Great Lakes Atmospheric Deposition Workshop held in Scarborough, Ontario (1986). A summary report of the workshop is now available from the IJC.

Visiting Chinese Scientist Departs

Dr. E Xue Li, Associate Scientist, Institute of Environmental Health Monitoring, Chinese Academy of Preventive Medicine, has spent the past year at NWRI training in quality assurance (QA) program design under the direction of **A.S.Y. Chau**. In China, Dr. Xue Li is responsible for a national QA water monitoring program. While at NWRI, he developed with Dr. V. Cheam a new method for ion-chromatographic determination of low levels of cadmium, cobalt and manganese in water, and assisted in the development of certified reference materials for organic compounds.

New Coordinator of LRTAP Program

Dr. D.S. Jeffries has been named Coordinator of the Long Range Transport of Airborne Pollutants (LRTAP) program for the Inland Waters Directorate, replacing **Mr. F.C. Elder** who retired in February. Dr. Jeffries, as Chief of the LRTAP program, has been responsible for the development of the Turkey Lakes Watershed Study, a multiagency, multidisciplinary calibrated catchment study in northern Ontario, and for assessing and modelling regional water quality data in support of emission reduction negotiations with the U.S. Dr. Jeffries is a member of the Federal-Provincial LRTAP Assessment Task Force and the Canada-Norway Project RAIN Technical Committee. **Dr. D.C.L. Lam** will replace Dr. Jeffries as LRTAP project chief.

NWRI/IDRC Alexandria Joint Project

Dr. K. Day, Rivers Research Branch, visited Alexandria, Egypt in April to advise Egyptian public health authorities on studies to determine the effects of *Damsissa* on non-target aquatic organisms. *Damsissa*, a plant toxin, is used in the control of snails which transmit the disease bilharzia. The project is funded by the International Development Research Centre of Canada (IDRC).

Dr. Day toured and selected field sites for future caged-fish assessment experiments and arranged for laboratory studies in Egypt and Canada to determine *Damsissa* toxicity to non-target organisms.

New Zealand Scientist Studies Hamilton Harbour

Dr. R. Spiegel, Senior Lecturer in the Department of Civil Engineering, Canterbury University, is spending an eight-month sabbatical at NWRI interpreting physical data to estimate the exchange of water between the harbour and Lake Ontario's western basin. This analysis will be important for the understanding of pollutant transport and retention in the harbour. His research in New Zealand focuses on the effects of depth-selective water withdrawal on the thermal stratification of drinking water reservoirs and on the effects of geothermal inputs on physical processes in deep mesotrophic lakes.

Scientist Invited to Finland

The Academy of Finland, at the request of the Finnish government, has initiated a series of evaluations of Finnish research programs to plan for the future. Environmental toxicology was recently identified for evaluation by internationally recognized experts chosen from names submitted by Finnish scientists. The names appearing most frequently were selected for the five-member evaluation panel. **B.J. Dutka**, Chief of the Ecotoxicology Project, Rivers Research Branch, was one of the five experts selected. He traveled to Finland in May to assess and report on the 20 Finnish research groups being evaluated.

Research Promotions

Drs. J.H. Carey and **B.G. Krishnappan** have been promoted to the third level in the Research Scientist category. This career stage recognizes a cumulative achievement distinctly above average and substantiates the leadership and excellence they have maintained in their respective fields of expertise.

Dr. Krishnappan, Rivers Research Branch, is an internationally recognized authority on coarse-grain sediment transport. He is best known for the development of models with practical application in predicting the distribution of dredge spoils and channel modification by sand. He is now turning his attention to the processes of fine-grain sediment transport.

Dr. Carey, Lakes Research Branch, is an internationally recognized authority on photooxidative degradation of organic chemicals and on the fate and effects of toxic contaminants in lakes

and rivers. He is best known for describing the degradation of the lampricide TFM in aquatic systems and the quantification of semi-conductor enhancement of photooxidation. He is presently the Project Chief of the Nutrient/Contaminant Interactions Project which is characterizing the influence of trophic state and biological production in lakes on the critical processes that control toxic contaminant fate and effects.

Drs. V. Cheam and H.B. Lee have been promoted into the Research Scientist category. Both scientists, who

work in the Analytical Chemistry Project, have been contributing to the advancement of analytical methods development for some time and have published extensively in their respective fields of expertise. Dr. Cheam is presently developing ion chromatographic methods for anions, cations and trace metals. Dr. Lee is studying ways to optimize the performance of GCMS (gas chromatography/mass spectrometry) instrumentation in analyzing halogenated organic compounds in environmental samples.

CCIW OPEN HOUSE '88

The Canada Centre for Inland Waters, home of the National Water Research Institute, opened its doors to the public from April 14-17. Over 35 000 regional visitors examined over 110 displays and demonstrations, making this year's edition of the triennial event the most successful yet. Open House is an opportunity for the interested public to learn about the research work carried out at NWRI and to meet the people "behind the scenes". The event was organized by a committee drawn from all agencies at CCIW under the chairmanship of J.D. Smith, Chief, Research Support Division, NWRI.

In his address at the opening ceremonies, D.L. Egar, Executive Director of NWRI, noted that "one of the important benefits of the Open House is that it provides a stimulus for all the staff here." "Scientists are people too", he pointed out, "who need a sense of appreciation, accomplishment and pride. The Open House provides it." Indeed over 750 staff members and their families attended an Open House staff night on April 13 to preview the results of their hard work prior to the public opening.

Open House '88 had something for everyone—young and old, kids and parents, educators and academics, business people and public officials. The media responded enthusiastically, with headlines and stories in five Ontario newspapers, and news coverage on four television and ten radio stations.

The broad spectrum of environmental displays and demonstrations was organized into various themes: Water in Motion; Aquatic Life; Flooding and Erosion; Charting; Ships and Instruments; Toxics; Acid Rain; Research Tools; Hamilton Harbour and Lake Restoration; Wastewater Treatment.

The five projects of the Rivers Research Branch were well represented. The Acid Rain Project (LRTAP) provided a video presentation of up-to-date scientific results on experiments from the Turkey Lakes Experimental Watershed in northern Ontario. A display of the RAISON (regional analysis by intelligent systems on a microcomputer) model, using microcomputer graphics, showed the aquatic resources currently at risk in eastern Canada, with predictions of acid rain effects for different sulphate load reduction strategies. Under the Toxics theme, the River Contaminants Project presented an elaborate display on the use of macroinvertebrates and mollusks as bioindicators, and the use of community change studies to indicate general levels of water pollution. The Ecotoxicology Project featured live *Daphnia* and a visual explanation of the LC₅₀ test for acute toxicity. The Groundwater Project opened its

analytical chemistry laboratory to show how organic contaminants are detected and measured by gas chromatography, and displayed its sophisticated techniques for monitoring subsurface waters. The River Modelling Project was very well represented under the theme Water in Motion. An operational scale model of a river proved quite a crowd pleaser, demonstrating ice jam formation and breakup using "model" ice in a meandering flume. The effects of agricultural and urban land use on drainage patterns were also explained through a model of the hydrosphere. A laser-beam particle size analyzer was set up to demonstrate the measurement and computer analysis of suspended sediment in rivers.

Continued on Page 8



Demonstration of ice jam formation and break-up using "model" ice in a meandering flume.

Continued from Page 7

Displays on the current state of Hamilton Harbour pollution and on the harbour's Remedial Action Plan (RAP) were the major contribution of Lakes Research Branch to Open House. The harbour exhibits included static displays, a video on oxygen restoration experiments, and a 3-dimensional model of the drainage basin. Also included were exhibits by the Department of Fisheries and Oceans, Canadian Wildlife Service, Ontario Ministry of the Environment and the Royal Botanical Gardens, which, together with the NWRI displays, gave a complete overview of the factors involved in preparing an ecosystem-based action plan for the harbour. 2500 people also participated in the "Hamilton Harbour Challenge", an interactive computer quiz on facts and issues relating to the harbour. This informal "poll" revealed that drinking water, waste disposal, air quality and wildlife habitat are viewed by the public as the major issues requiring attention. Responses to the poll rein-

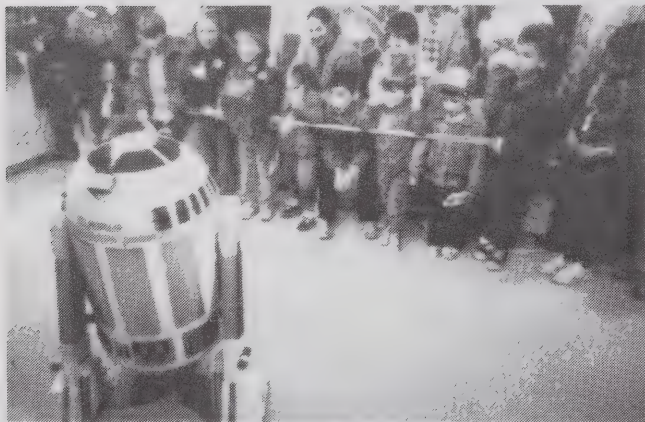
forced the public values and principles enunciated by the Hamilton Harbour Stakeholder Group involved in the development of the harbour RAP. Drinking water was viewed as the biggest issue, but air quality, not addressed by the RAP committee because of the focus on water quality, was also highlighted as an important factor affecting use and appreciation of the harbour.

Other Lakes Research Branch's contributions of note included organochlorine contamination in snapping turtles around Lake Ontario, Chernobyl radionuclide fallout in rainfall, and oligochaete worms from contaminated sediments. The scientists manning the displays were impressed that the public, particularly the older generation, was so concerned and so knowledgeable about the links between society's activities and environmental pollution.

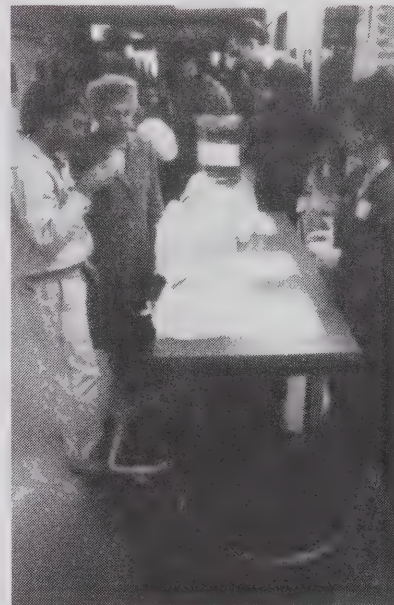
The theme Water in Motion formed the major part of the exhibits of the Hydraulics Project, Research and Application

Branch. In conjunction with Open House, the staff of the Hydraulics Laboratory held a special VIP reception for potential clients. Over 20 representatives of consulting companies, universities and other government departments toured the facility and met the staff. In addition to the Hydraulics exhibits, the Analytical Chemistry and QA/QC projects in the Research and Application Branch demonstrated a number of environmental techniques. Visitors were fascinated with the robotics equipment used in laboratory automation.

The enthusiastic crowds who attended Open House '88 reminded CCIW employees that individual Canadians do care about the environment and that, as an editorial in The Hamilton Spectator noted, "public sentiment is on the side of the scientists in the constant struggle to preserve our irreplaceable fresh waters."



NWRI's Research Support Division's RU4H2O robot, first built for the 1982 Open House, is extremely popular with the younger children. Powered by batteries and employing a two-way radio communication system with a hidden operator using a standard model airplane controller, the Robot moves about and discusses environmental issues with children in the crowd. Photo by: J. Dolanjski



"How can you tell how clean the drinking water is? Can you tell by tasting it?" Four types of water were tested and the poll revealed that most people prefer bottled spring water (42%) to the chemically pure distilled water (9%). The local city water ranked third (11%). It is interesting to note that bottled water also comes from a well. This survey was organized by the Groundwater Contaminant Group, Rivers Research Branch. Photo by: J. Dolanjski

RESEARCH FOCUS

The Air-Water Interactions Project

Atmospheric deposition of pollutants to surface waters has long been established as a "pathway" in the environmental cycling of a number of toxic chemicals of concern. Since the mid-1960s, DDT has been reported from such widely separated locations as the Arctic, the Antarctic, mid-Pacific and industrial Europe. Global dispersion is clearly indicated by such observations as well as by the case of the Chernobyl radionuclides which travelled quickly around the planet.

Despite the recognition that air-water interactions are important processes in toxic chemical pollution, our knowledge base in many areas is very weak—sufficiently so that answers to specific questions such as the relative significance of the atmosphere in the loading to surface waters cannot yet be answered for many persistent chemicals. Atmospheric inputs are generally thought to occur by three basic mechanisms. Wetfall, including both rain and snow, has been the main focus for most monitoring to date. In the Great Lakes, sufficient data now exist to permit reasonably sound loading estimates for several chemicals in individual lakes. On the other hand, dryfall of air-borne particulates has not yet been investigated extensively, except on a theoretical basis. Two aspects of this problem are particularly important—the rates of deposition of different size fractions of particulates under natural conditions and the environmental concentrations of toxic chemicals within each size fraction. The third mechanism is the direct transfer of toxic chemicals in the vapour state between the atmosphere and surface water. This process can take place in both directions and is determined by a number of factors, including the Henry's Law constant for the chemical and the concentration gradient at the air-water interface. Much of this information is known only on a theoretical basis.

Because of the large knowledge gaps, there is a great deal of uncertainty in

current estimates of toxic chemical inputs to the Great Lakes from the atmosphere. Nevertheless, these inputs are substantial and probably represent the largest source of chemicals such as lead, polychlorinated biphenyls (PCBs), the hexachlorocyclohexanes (HCHs) and some of the polynuclear aromatic hydrocarbons (PAHs). The objective of the Air-Water Interaction Project is to resolve some of these uncertainties and to create reliable mass balance estimates of the cycling of these and other chemicals into Canadian aquatic ecosystems, the Great Lakes in particular.

Monitoring atmospheric deposition. Rain sampling for organic contaminants has been conducted for several years and reliable data are available for most areas of Canada except the Far North. Patterns of deposition are similar throughout the country with the more prominent contaminants being PCBs, α -HCH and lindane (an isomer of α -HCH). These compounds can occur at levels in excess of 1 ng/L averaged over the seasonal rainfall period. Data for snow are much poorer but the levels in snowmelt appear to be lower than for the rain. Concentration data for a number of organochlorine contaminants in rain will continue to be gathered and the work expanded to include some

PAHs as well as the chlorobenzenes. An all-weather sampler is also under development and should greatly improve the capability to assess snowfall reliably and to sample in the Far North, an area of particular federal responsibility. A completed prototype will be field-evaluated over the coming year. A second new sampler, which has been developed by the Atmospheric Environment Service with input from NWRI, is also being tested. Wide-spread use of these two samplers should provide the important data on the composition of toxic chemical pollutants found in the atmosphere. The sources of these chemicals may be local in some cases (the metals for the most part) or they may be distributed on an intercontinental scale.

Chemical deposition is not limited to lakes. Bogs, with inputs only from the atmosphere, are proving useful in estimating the atmospheric deposition of persistent organic compounds. This approach will be examined further. Other forms of vegetation will also be investigated for their possible use in providing trend data, and as an economical method of sampling atmospheric burdens of selected chemicals. This aspect of the project will investigate both the persistent organic compounds and the heavy metals.



Toxic rain research sampling sites.

Modelling air-water exchange. A primary objective of the Air-Water Interactions Project is to develop numerical models to predict the contribution of toxic chemicals to Canadian surface waters from the atmosphere. A small lake (Little Turkey Lake near Sault Ste. Marie, Ontario) that has already been extensively sampled in the acid rain program will provide the biogeochemical data base to validate the toxic-rain models under development. The experience studying this lake in the field, in the laboratory and in the computerization of relationships will be used to develop models for a much larger and more complex system — Lake Ontario. This lake is known to be contaminated with several chemicals that are transported and deposited via the atmosphere. The ecosystem compartments that are being studied include suspended solids, water column and sediments in the lake, and particulates, vapour, rain and snow in the atmosphere.

Accurate rate measurements of the processes which govern the transfer of toxic chemicals between the atmosphere and water are the key to a successful modelling effort. Volatilization of persistent organic chemicals from the water surface to the atmosphere is an important and poorly understood reaction in the overall mass balance equations for these chemicals. A large wave flume in NWRI's Hydraulics Laboratory is currently being

modified to provide sealed air and water recirculation so that the impact of water turbulence on the mass transfer coefficients of selected organic chemicals can be measured for the first time. Wind velocities up to 65 km/h will be possible. The first tests will use lindane, a relatively water-soluble pesticide with a modest vapour pressure. Both air and water will be monitored and wave conditions determined using sensitive instrumentation for characterizing the boundary layer.

Radionuclides. Radionuclides in Canada's surface waters are a concern in the vicinity of point sources such as mining sites and at nuclear power and fuel reprocessing facilities. Investigations are under way to establish the presence and cycling of these substances in surface waters, including methods to estimate the degree of exposure to aquatic life. Present investigations are concerned with the role of surface films in dispersing these substances and their overall distribution in the aquatic ecosystem.

Climate Change. In addition to the "toxic rain" issue, the project is also addressing related air-water questions concerning the impacts of climate change on lake systems. Interpretation of pre-historic paleolimnological data is being used as a tool to predict water quality changes. Water quantity and temperature effects are also being assessed, using physical heat and

circulation models of Lakes Ontario and Erie.

Project Chief: W.M.J. Strachan

Study Leaders: L.D. Delorme, M. A. Donelan, W.A. Glooschenko, R.F. Platford, W.M. Schertzer

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The Ecotoxicology Project

There are presently in use in Canada some 30 000 different chemicals, many of which eventually find their way into the aquatic environment. How can we tell where they are building up before they cause serious problems? Ecotoxicological and microbiological tests are among the most important means of assessing the impact of pollutants on the quality of water and aquatic sediments. These methods provide an estimate of the degree of chemical contamination in the environment and identify potential ecological impacts. They are also useful for understanding a number of contaminant/biota interactions such as: biological acclimatization; transport rate in fluvial systems; biodegradation, bioaccumulation and

other food chain effects; growth stimulation or inhibition; and effects of remedial activities.

The principal objective of the Ecotoxicology Project, Rivers Research Branch, is to develop a comprehensive "battery of tests" protocol for chemical stress assessment in fresh water systems through appropriate research into contaminant/biota interactions. Once this multiple testing protocol has been developed, it will be transferred to operational agencies in government and to the private sector for implementation in monitoring and regulatory programs.

There is now general acceptance that no single criterion can be used to judge

adequately the potential hazard (either to the environment or man) of a given pollutant. Thus a multitude of biological assay procedures have been, and continue to be, developed to assess toxicant impacts. Industrial pollutants and toxicants, such as herbicides, insecticides, fertilizers and car exhaust fumes, affect biotic systems at different levels. Therefore, a "battery approach", utilizing several different short-term biological tests, can be used to advantage in any monitoring scheme. Investigators are now experimenting with various combinations of ecological and health effect tests to estimate the toxicity and mutagenicity of effluents, waters and sediments as well as the bacteriological hazards they contain.

Ecological effects tests are conducted mainly to measure the acute toxicity (quick killing power) of chemicals as well as their ability to cause genetic or mutagenic damage to the offspring of aquatic organisms at all trophic levels of the food chain. To help estimate chemical toxicity in natural and polluted ecosystems, bacteria, algae, zooplankton, benthic invertebrates and fish are used as the test organisms.

Bacteria and enzymes may be exposed to a wide range of toxic, organic and inorganic compounds in natural water, soil, leachates, sediments, sewage treatment processes and industrial discharges. The toxicity of any compound or group of compounds depends on the environmental parameters as well as on the microorganism or enzyme system being tested. The compounds may be metabolically altered to nontoxic metabolites or may exert a direct toxic action on microbial populations. Microbes also may be subjected to synergistic or antagonistic effects from different components of contaminant mixtures. In sewage treatment plants, toxicants may cause shifts in microbial populations, and this may adversely affect the operation of the plant. Toxic and mutagen action depends on concentration. For example, phenol can be metabolized at low concentrations, but it becomes toxic at high concentrations. Toxicant action also depends on the presence of other chemicals in solution.

Criteria for bioassays. All the above factors have been considered in the development of the following criteria for an appropriate "battery of tests" for ambient receiving waters and sediments: the tests must be simple enough to carry out in simple test laboratories without the use of sophisticated instruments or training; results should be obtained on the same day or within 48 hours; materials and manpower should be inexpensive; the proposed battery must be able to provide information on the effects of both bacteriological and toxicological hazards; and the tests must be able to work in all parts of Canada, under a variety of pollution conditions, so that Canada-wide priority hazard screening can be undertaken.

With these criteria in mind, the scientists in the Ecotoxicology Project set out to

develop a battery of "core tests" which could be applied Canada-wide. It is recognized, however, that at specific sites the core battery of tests will need to be augmented with other tests tailored to the site conditions and monitoring goals.

Approximately 220 water and sediment samples have been collected from polluted and unpolluted streams, rivers, lakes and harbours, extending from Saint John Harbour in New Brunswick to the mouth of the Fraser River in British Columbia. When the project started in 1985, the concentrated and unconcentrated water samples were each tested ten times. The sediments were initially extracted with ultra pure water, and the water extract tested for toxicants. As the project continued, it was decided also to evaluate the toxicity of organic pollutants bound to the sediments as they may be recycled into the food chain by the action of various microbiota. To achieve this we use a dichloromethane extraction, then exchanged into DMSO (dimethylsulfoxide).

Data from these samples, collected across Canada, are still being analyzed. The following preliminary observations, however, can be made:

- The fecal coliform membrane filter (MF) test and the coliphage test (viruses infecting *E. coli*) will probably be used for water bacteriology. These tests indicate the presence of fecal pollution and inefficient sewage treatment plant operation.
- In sediments, the bacteriological tests of choice will probably be the A-1 MPN (most-probable-number, 5 tube test) broth test for fecal coliforms and the *Clostridium perfringens* spore test. These procedures provide an indication of contemporary fecal pollution as well as historical pollution over the previous 1-2 years (*Clostridium*).
- Tests for coprostanol, cholesterol and dehydrogenase activity proved either to be insensitive (dehydrogenase activity) or too variable and expensive (coprostanol and cholesterol) to be used routinely in a battery of tests by all laboratories. These tests, however, would have some use at specific sites involving sewage treatment plant efficiency, especially coprostanol.

- It would appear that the *Daphnia magna* test may be the most sensitive and economical test for screening of water and sediment-water extracts for toxicants.

- Preliminary statistical analyses indicate that the Microtox test is rather insensitive to toxicants in our water and sediment water extracts. A final decision on the Microtox test and the other tests being evaluated for toxicant screening must await additional scrutiny and statistical evaluation of the data.

Our final goal is to develop a basic battery of five to six tests which can be applied successfully in routine laboratory use without escalating costs and the purchase of specialized, expensive equipment.

Project Leader: B.J. Dutka
Project Team: B.J. Dutka, K. Jones, A. Jurkovic, K.K. Kwan, R. McInnis, S.S. Rao, P. Stewart

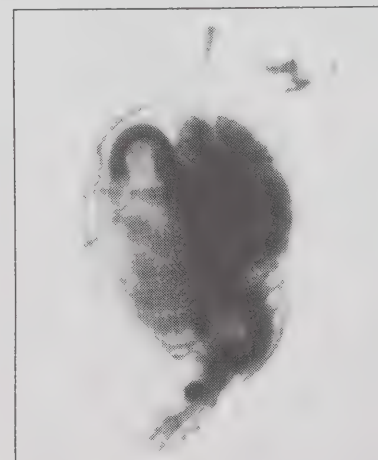
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COMING EVENTS

August 15-18, 1988. **Trace Metals in Lakes.** This international conference will be held at McMaster University, Hamilton. About 120 abstracts have been received from many different countries, covering every aspect of trace metal contamination of lake ecosystem as well as cycling and bioavailability of metals. A short course on clean-lab techniques is being organized to complement the conference. The proceedings will be published in "Science of the Total Environment". For more information, contact Drs. J.O. Nriagu or K. Lum at (416)336-4784/4617.

August 29-September 2, 1988. **First Biennial Water Quality Symposium: Microbiological Aspects.** This major symposium will be held in Banff, Alberta and will focus on microbiological contamination and hazards in water and on methods to assess and remove these problems. For more information, contact the organizers, B.J. Dutka or Dr. D.R.S. Liu, at (416)336-4576/4923.

October 10-14, 1988: **The Fate and Effects of Toxic Chemicals in Large Rivers and their Estuaries.** This international symposium is being organized jointly by NWRI and Institut National de la Recherche Scientifique-Eau. It will be held in Quebec City. The focus of the conference will be on the transport mechanisms, positioning, fate and effects of toxic chemicals as detected by ecotoxicological methods. Several keynote papers from specialists in western Europe and the U.S. will be presented. For more information, contact Dr. R.J. Allan at (416)336-4678.



Canada's principal Great Lakes research ship, CSS Limnos is a general-purpose scientific vessel. Based at the Canada Centre for Inland Waters in Burlington, Ontario, the Limnos sails throughout the Great Lakes on research and monitoring voyages for NWRI, other elements of Environment Canada and the Department of Fisheries and Oceans.

About NWRI

Environment Canada's National Water Research Institute (NWRI) conducts a national program of original research and development in the aquatic sciences, in partnership with the international freshwater science community. The twin goals of the Institute are to advance scientific understanding of national and international water issues important to Canada and to develop knowledge and authoritative expertise on these issues that can be used by Environment Canada to influence decisions affecting the wise management of Canada's water resources.

Research at NWRI is conducted within multidisciplinary projects, each focusing on a priority issue. Projects are grouped within three branches, the Lakes Research Branch, the Rivers Research Branch, and the Research and Applications Branch. Current long-term research priorities include: toxic chemicals in the Great Lakes and the St. Lawrence River; exchange of toxic contaminants between air, water, sediments, and biota; groundwater contamination; pesticide contamination in rivers; acid rain; lake rehabilitation; and aquatic monitoring, ecotoxicology, and risk prediction methodologies.

NWRI Digest

The NWRI Digest is the quarterly public newsletter of the National Water Research Institute, Conservation and Protection, Environment Canada. Suggestions, comments and further enquiries concerning newsletter items are welcomed. Please write to the Editor, NWRI Digest, National Water Research Institute, P.O. Box 5050, Burlington, Ontario, Canada L7R 4A6.

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Aquatic Protection: A National Workshop

The new Canadian Environmental Protection Act (CEPA), together with other federal and provincial legislative initiatives, provides the policy framework for a modified approach to protecting the Canadian aquatic environment. The traditional chemical approach used to assess pollutant hazards in Canadian waters and sediments should be changed to encompass a combination of chemical and biological toxicity tests. While the theoretical benefits from incorporating biological tests and standards into regulations are well recognized, there are reservations about the current level of scientific knowledge and practical expertise available to formulate and implement such regulations.

As a government agency involved in ecotoxicological research, we are conscious of the fact that different stakeholders have differing views on such issues as the types of biological tests to be used; the uncertainty arising from knowledge gaps; the modification of regulatory criteria as

knowledge improves; the government role in R&D relative to the private sector; and the transfer of technology from government laboratories to the private sector and universities. A national workshop, hosted by Conservation and Protection (C&P), and organized and chaired by NWRI, was held April 26-28, 1988, in Alliston, Ontario. The workshop, entitled "Biology in the New Regulatory Framework for Aquatic Protection", was designed to promote discussion among decision makers and experts from all key sectors (federal, provincial and municipal agencies, industries and private consultants and laboratories).

Invited speakers provided an overview of biological toxicity methods used in Canada as they relate to CEPA, the Ontario's Municipal and Industrial Strategy for Abatement program (MISA), and the Pest Control Products Act. Industry and the private consulting sector were invited to discuss the benefits, problems and economic opportunities generated by this legislation. The participants, divided in working groups, debated several important questions such as the benefits and limitations of biological toxicity tests as compared to other possible methods and strategies, e.g., the chemical-specific approach, and the role of government in research and development of biological toxicity tests, quality assurance/quality control (QA/QC) and monitoring and assessment.

Consensus was reached within the working groups on the following preliminary recommendations:

- For regulatory purposes, both laboratory and field biological toxicity tests should be used in conjunction with chemical methods. The ideal protocol for assessment of ecosystem hazard and dysfunction would be a tiered approach: initial screening by short-term acute and chronic toxicity tests followed by more comprehensive ecotoxicological tests involving several trophic levels.

- In the case of hazard assessment, it is the responsibility of government to set clear and precise regulations regarding the use of biological toxicity tests. Standard protocols should therefore be developed by government for those tests that are already well-proven and in active use. As new tests become available, government should provide matching standardized protocols.

- In government laboratories, state-of-the-art effects assessment research must be maintained in support of federal program initiatives, QA activities and contract review functions. Research results should be transferred to the private sector for routine use.

- Neither government nor university laboratories should enter into competition with the environmental service sector in the provision of routine biological monitoring or testing services to industry. Government should ensure appropriate QA/QC while responding to its mandated needs.

- All toxicologists and laboratories carrying out biological toxicity tests should be accredited. Self-assessment should be the rule within industry, but government should be responsible for periodic audits.

- It is the government's role to assess or evaluate the effectiveness of existing regulations in the receiving environment and to identify emerging or unpredicted problems that need to be addressed by regulatory agencies.

- The maintenance of long-term data sets for the biomonitoring of impacts on large areas must be conducted by the government and not left to industry.

A full report on the proceedings of the workshop will be completed in late fall 1988 and distributed to interested parties upon request.

Dr. E.D. Ongley
Director
Rivers Research Branch

INSIDE

- Inaugural R.A. Vollenweider Lecture in Aquatic Sciences
- Modelling River Ice Regimes
- Brazil Ice and Winter Power Production
- Great Lakes Sediment Data Base
- New Analytical Methods
- Toronto Conference on the Changing Atmosphere
- Sustainable Development of the Waterford River Basin
- Annual Great Lakes Research Conference
- Deltamethrin Impacts in P.E.I.
- International Collaboration
- Public Awareness
- Nearshore/Offshore Interactions Project
- Quality Assurance Project

RESEARCH NEWS

Inaugural R.A. Vollenweider Lecture in Aquatic Sciences

Dr. Curt G. Forsberg, Professor of Limnology and Director of the Institute of Limnology, University of Uppsala, Sweden, was the first recipient of the annual NWRI Vollenweider Lectureship in Aquatic Sciences. He delivered his lecture "Limnological Research and Water Management", on June 8, 1988, to staff from the Canada Centre for Inland Waters, and a number of visiting scientists from eastern Canada. An informal discussion on research collaboration with universities, and a debate on the future of limnology, moderated by Dr. J. Barica, Lakes Research Branch, took place following the lecture.

Dr. Forsberg spent two days at the Model Lakes Experimental Site with Dr. J.H. Carey, Lakes Research Branch, to familiarize himself with NWRI field research. He also enjoyed a tour of Hamilton Harbour and the Wastewater Technology Centre at CCIW.

The inaugural Vollenweider Lecture was considered a success and an important milestone in establishing NWRI's formal ties with the international science commu-

nity. Nominees for the 1989 Lectureship will be solicited from the Canadian water research community this fall.



Official presentation to Dr. Curt G. Forsberg of the "R.A. Vollenweider Lectureship in Aquatic Sciences". From left to right: Mr. D.L. Egar, Executive Director, NWRI; Dr. Curt G. Forsberg; Dr. R.A. Vollenweider; Mr. D.A. Davis, Director General, Inland Waters.

Modelling River Ice Regimes

A major research project to develop a comprehensive numerical model on river ice regimes has been funded under the Supply and Services Canada (DSS) Unsolicited Proposal Program. The broad objective of the project is to produce a predictive river ice model capable of simulating the complex phenomena of water cooling, ice generation, thickening, shoving, eroding, melting and break-up. Dr. S. Beltaos of the Rivers Research Branch has been named scientific authority for the project.

The proposal was formulated by a consortium of consulting firms (Tecsult, Acres, LaSalle Hydraulics Laboratory and Lavalin) assisted by the National Research Council of Canada (NRC) Task Force on Numerical Modelling of River Ice Conditions. Total project costs are estimated at \$1.7 million. Costs will be shared by DSS, the Canadian Electrical Association, In-

land Waters Directorate (IWD), Ontario Hydro, New York Power Authority, Manitoba Hydro, Hydro-Québec, Indian and Northern Affairs Canada and the Ontario Ministry of Natural Resources.

The private sector participants will have primary responsibility for designing, testing and documenting the model and for model simulation. IWD (Water Planning and Management Branch) and NWRI will develop the programming and assist the private sector in testing and documenting the model. The other co-sponsors and additional interested agencies will supply field data and provide numerical modelling and river ice expertise related to their own programs. The NRC Sub-Committee on the Hydraulics of Ice-Covered Rivers will have an advisory role and will maintain liaison between the project group and the large number of potential users of the completed model.

Frazil Ice and Winter Power Production

The adhesion of frazil ice to water intakes and the formation of anchor ice can, in extreme cases, shut down hydro-electric facilities. Little is known of the physical properties of frazil and anchor ice. A better understanding of the physical processes would help in managing rivers for effective winter power production. Dr. G. Tsang, Rivers Research Branch, is currently conducting a three-year laboratory study of the basic physics of anchor ice formation and of frazil ice evolution and flocculation with the financial assistance of Ontario Hydro. It is hoped that this work will lead to stronger research collaboration with the industry in support of their future needs.

Great Lakes Sediment Data Base

Provincial agencies, conservation authorities, universities, consulting firms, the International Joint Commission, as well as various federal departments, often need comprehensive data on the bottom sediments of the Great Lakes. However, access to the 20-year sediment data records within Environment Canada's NAQUADAT data base has been difficult. Data retrieval was limited to printed listings and maps from two separate files, only one of which was machine-readable. To improve access to this vast set of data,

Dr. N.A. Rukavina, Lakes Research Branch, has just completed a project, supported by Conservation and Protection's Baseline Studies Fund, which combines offshore and nearshore data in a machine-readable file. The new file comprises chemical, physical and descriptive data for more than 4000 samples from all of the Great Lakes, including Lake Michigan. Selective retrieval of the data is possible through the standard retrieval programs of NWRI's SYSTEM 2000 data base, or through two specialized retrieval

programs written specifically for the sediment file. The organization of the data in a consistent and readily accessible format should increase its utility as a resource for research, engineering and assessment studies. NWRI's NAQUADAT data base is managed by the Research Support Division. Requests for information are welcome and should be directed to the Head, Computing and Programming Services.

New Analytical Methods

New and improved analytical methods are continually being developed within the Analytical Chemistry Project, Research and Applications Branch. These methods are required to address specific needs of water pollution research and monitoring programs.

Reliable alkalinity measurements are needed to monitor the effects of acid precipitation on aquatic ecosystems. Existing procedures are satisfactory for hard and medium-hard waters, but have serious deficiencies in low alkalinity waters. Dr. I. Sekerka and J.F. Lechner have developed a new method for the determination of total alkalinity in natural waters using flow injection analysis (FIA) with conductivity detection. This new method is simple, fast, sensitive and reliable, and eliminates many of the limitations of existing methods.

Surfactants are widely used in industrial, commercial and domestic applications and are often discharged into municipal and industrial wastewaters. They cause foam buildup in rivers and reservoirs, reducing oxygen levels in the water and thus posing a threat to fish populations. Dr. F.I. Onuska and K.A. Terry have developed a novel method for the separation and quantitative determination of some non-ionic surfactants in water (linear alkylene oxide-fatty alcohol condensates), using capillary supercritical fluid chromatography (SFC). Previous techniques for the determination of this important group of non-ionic surfactants did not provide adequate information about their biodegradability. High recoveries and precision are obtained with this novel SFC method, which allows for selective isolation of both

the surfactants and their polyglycol breakdown products. This is the first time that quantitative results using SFC have been reported in the field of environmental chemistry.

Synthetic pyrethroids, such as permethrin, cypermethrin, deltamethrin and fenvalerate, are recently developed insecticides used for the control of pests in farmlands and on vegetable crops. They have been registered in Canada since the early 1980s and are being considered as potential replacements for organochlorine, organophosphorus and methylcarbamate insecticides. Pyrethroids are less persistent in the environment and less toxic to mammals than other insecticides. They are, however, highly toxic to fish and other aquatic organisms. In order to protect aquatic ecosystems, it may be necessary to monitor pyrethroid levels in rivers, lakes and ponds adjacent to areas where the insecticides have been applied. To this end, a gas chromatographic method for the quantitative determination of the above mentioned pyrethroids and their major metabolites in water samples has recently been developed by Dr. H.B. Lee and E.A. Kokotich.

References

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Toronto Conference on the Changing Atmosphere

Dr. R.J. Daley, Chief, Science Liaison Division, NWRI, and Dr. V. Klemes, Senior Scientist, National Hydrology Research Institute, Saskatoon, helped to plan and conduct the Working Group on Water Resources at the late June policy conference on the "Changing Atmosphere: Implications for Global Security". The very successful conference, organized by Environment Canada's Atmospheric Environment Service, brought together 300 prominent scientists and policy makers from eight countries to recommend actions to reduce the future impacts of global air pollution. Dr. Daley served as facilitator and Dr. Klemes as rapporteur for the water group.

There was strong consensus that many of the most destructive impacts of global atmospheric change will be associated with changes in regional water resource systems. An urgent action plan, based on the principles of global equity, international cooperation, open technology transfer and public involvement was recommended. Specific proposals were made with respect to water resource policy, water quality protection and future research needs. Copies of the Conference Statement and Water Resources Working Group Report can be obtained from the Editor, NWRI Digest.

Sustainable Development of the Waterford River Basin

Water resources in the Waterford Basin, Newfoundland, have been affected by urbanization, which can lead to a deterioration of surface water quality and increased flood risk. Future urbanization relating to offshore oil development may aggravate the situation. To mitigate these adverse effects and to develop a water management plan for the basin, a comprehensive study was jointly conducted by Inland Waters Directorate (Atlantic Region), Environment Newfoundland and NWRI.

NWRI took the lead role in developing the methodology to predict impacts of future development on flows in the Waterford River. A continuous hydrologic simulation model was calibrated for the existing catchment conditions and then applied to

future land-use scenarios. Results indicate that future urbanization, while not increasing runoff volume, will increase the incidence of flooding because of increased speed of runoff. Such increases can be counteracted, however, by proper management of storm water, including runoff detention and preservation of natural drainage.

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Ng, H.Y.F. and J. Marsalek. 1987. Streamflow modelling using HSPF. Urban Hydrology Study of the Waterford River Basin, Technical Report No. UHS-WRB 1.12, Environment Newfoundland, St. John's, Nfld.

Ullah, W., J. Marsalek, T. Hennigar and T. Pollock. 1988. Waterford River Basin, Newfoundland. Proc. of the Canadian Hydrology Symposium 88, Canadian Research Basins, Banff, Alberta, May 9-11, 1988.

Deltamethrin Impacts in P.E.I.

The persistence and fate of deltamethrin, a pyrethroid insecticide, has been studied in Prince Edward Island. Deltamethrin was carefully sprayed on a small experimental pond and stream and its disappearance and degradation monitored over time by NWRI scientists.

The insecticide disappeared quickly from the water (half-life of about 1 h). Deltamethrin was transformed to non-toxic stereoisomers through chemical and photochemical isomerization and was hydrolyzed with subsequent oxidation of products. No residues of deltamethrin or its four major degradation products were found 11 days after the spray. Laboratory studies indicated that volatilization from the water microlayer surface was very fast, suggesting that this process may be the major route of dissipation for this insecticide and other similar lipophilic pesticides when sprayed on water.

Although the NWRI study demonstrated very low persistence of deltamethrin in water, retention and strict enforcement of the 100-m buffer zone between sprayed fields and water bodies is recommended because of the extremely high toxicity of deltamethrin to aquatic organisms.

Reference

Maguire, R.J., J.H. Carey, J.H. Hart, R.J. Tkacz and H.B. Lee (1988). Persistence and fate of deltamethrin sprayed on a pond and stream in Prince Edward Island. NWRI Contribution No. 88-14.

Annual Great Lakes Research Conference

The 31st annual conference of the International Association for Great Lakes Research (IAGLR) was held at McMaster University, Hamilton, Ontario, in May. NWRI co-hosted the meeting with McMaster University, the Inland Waters Directorate in Ontario Region, and the Department of Fisheries and Oceans. Thirty-four of the 225 conference papers in aquatic physics, chemistry and biology were presented by NWRI scientists. Discussions at the conference focused on four major issues: the environmental status of Lake Ontario; future climate change and its effects; pollution "hot spots" in the Great Lakes; and research in

support of the Remedial Action Plan for Hamilton Harbour.

Special sessions were also held on "Management Perspectives and Policy Coordination in Great Lakes Research", and "Toxic Contaminants: Are We Asking the Right Questions?" Both the public and the scientific community were invited to discuss the latter subject at an evening session. The President of IAGLR, Dr. K.L.E. Kaiser, Lakes Research Branch, presented Dr. P.G. Sly, NWRI scientist and past President of IAGLR, with the Anderson Everett Award in recognition of his continuing contribution to the association's activities.

S T A F F N E W S

International Collaboration

Dr. M. A. Donelan, Research and Applications Branch, has been selected as a Canadian member of the Scientific Committee on Oceanic Research (SCOR) of the International Council of Scientific Unions. Dr. Donelan has also been nominated for the position of SCOR Vice-President. SCOR is the principal international scientific organization involved in ocean research. Its programs encom-

pass all disciplines and address many issues of importance to Environment Canada, including coastal-offshore ecosystems, climate change, wave modelling, and experimental ecosystems. Dr. Donelan's participation on SCOR is expected to enhance departmental opportunities for international scientific leadership on these important issues.

The International Association of Water Pollution Research and Control has formed a specialist group to support studies on hazard assessment and control of environmental contaminants. **Dr. J.H. Carey**, Chief of the Nutrient/Contaminant Interactions Project, Lakes Research Branch, is one of two Canadian appointees to the group. The group will foster better communications of new methods

for monitoring contaminants and for predicting their fate and effects in the environment. The long-term objective of the group is to optimize contaminant control systems on a global basis.

Anne Guillaume, research scientist at the Direction de la Météorologie Nationale in Paris, France, will be a guest scientist at NWRI until November 1988. Ms. Guillaume, who is in charge of French wave modelling and forecasting efforts, will collaborate with Dr. M.A. Donelan of the Research and Applications Branch.

Results from NWRI's wave measurement program at the coastal research tower in Lake Ontario will be used to improve the physics of the French wave model "VAG". Concurrently, a wave propagation scheme will be added to NWRI's wave model so that it can be applied to water bodies where wave swell is significant. This initiative is part of the bilateral scientific program between France and Canada.

Jian Hua Weng of the Water Quality Research Centre, Beijing, People's Re-

public of China, is spending a year as a guest scientist with Rivers Research Branch. Mr. Weng's specialties are synthetic and physical organic chemistry and the chemistry of air pollutants. At the Water Quality Research Centre, he is engaged in water quality analysis and assessment, wastewater treatment, and research on the kinetics of degradation of xenobiotics. Mr. Weng will collaborate with Drs. R.J. Maguire and D.L.S. Liu on the aquatic persistence and fate of dye-stuffs in the Yamaska River basin, Quebec.

PUBLIC AWARENESS

Children's Environmental Festival

As part of Environment Week 1988, NWRI hosted a major children's environmental festival. The festival, which ran from May 30 to June 5, was organized by "Public Focus" a Toronto-based, non-profit group dedicated to educating children about environmental problems and their solutions. NWRI helped to plan the festival and provided full on-site logistical support.

Approximately 5000 grade 4, 5 and 6 students from Burlington, Oakville and Hamilton visited the festival, enjoying the various activities and the excellent weather. Another 3000 members of the general public visited the festival during the weekend.

Six large tents erected on grassland alongside the Skyway Bridge were used to house bright and easy-to-understand displays and action games such as "Environmental Twister" and the "Recycling Relay Race". There was also a puppet show and two troubadours singing environmental songs.

Displays were also situated in the main mall of CCIW and environmental plays were presented in the Auditorium. The festival, which stressed the theme "Make a Difference in Your World", was praised by teachers, school boards and local community leaders as an effective and entertaining way to promote environmental awareness. NWRI hopes to welcome the festival back again next year.

Royal Visit to NWRI

Her Majesty Queen Beatrix and His Royal Highness Prince Claus of the Netherlands visited the National Water Research Institute on Friday, May 13. Inclement weather notwithstanding, their visit was clearly a great success. The royal visitors were welcomed by the Honourable Tom

McMillan, Minister of the Environment, and were provided with a briefing on research conducted at the Canada Centre for Inland Waters by Dr. R.J. Allan, Director, Lakes Research Branch, with special emphasis given to the many collaborative activities that occur between Canada and the Netherlands. The royal couple indicated a keen interest in the variety of research displays presented in the Hydraulics Laboratory. Her Majesty was impressed by the warmth of her welcome to the Centre.

Advice to Marathon Swimmer Vicki Keith

Advice from NWRI staff was sought on several occasions by members of the Coaching Team for marathon swimmer Vicki Keith during her swim across all five Great Lakes this summer. Information was provided on currents, waves and water temperatures. NWRI applauds Vicki's accomplishment and is proud to have assisted her in reaching her fund-raising goal for a swimming pool for physically disabled children.



Her Majesty Queen Beatrix and His Royal Highness Prince Claus observe demonstration of robot used in NWRI's analytical chemistry laboratories.

RESEARCH FOCUS

Nearshore/Offshore Interactions Project

Most environmental contaminants enter our lakes from local sources, e.g., effluent pipes or polluted tributaries. Once in the nearshore waters, these contaminants are dispersed into offshore waters by a variety of complex and poorly understood mechanisms. They are incorporated into food chains, volatilized into the atmosphere, degraded or buried with sediments, or transported with currents. For instance, mirex, an insecticide and flame retardant, entered Lake Ontario from the Niagara and Oswego rivers. Mirex is now found throughout Lake Ontario and at near uniform concentrations in most fish species, waterfowl and shore birds. Furthermore, mirex has been detected down the full length of the St. Lawrence River into the St. Lawrence estuary, where it is present and perhaps bioaccumulating in Beluga whales.

When taken individually, the various processes controlling the fate and effects of contaminants are relatively easy to measure in the laboratory. In nature, however, these processes are occurring simultane-

ously, often in concert or competition with each other. Moreover, their relative importance and rates can be influenced by many factors, e.g., pH, wave action and biological growth. Rapid fluctuations of these factors are most noticeable in the nearshore waters. As a result, contaminant pathways in these waters are more difficult to understand.

The objective of the Nearshore/Offshore Project within Lakes Research Branch is to combine physical, chemical and limnological expertise with chemical and biological expertise to assess the transfer, degradation, adsorption, volatilization, burial, resuspension and biological impacts of contaminants in this important but poorly understood zone. Modelling is a major aspect of the project, which includes both physical hydrodynamics and chemical prediction through quantitative structure activity relationships (QSAR). Research is conducted in the St. Lawrence River, its lakes and estuary, and in the Laurentian Great Lakes Connecting Channels.

St. Lawrence River

Project studies are done principally in the riverine lakes and the upper estuary of the St. Lawrence River and focus on locating major sources of contaminants and on the establishment of mass balance budgets for critical contaminants. Water, suspended sediments and bottom sediments are analyzed to obtain concentration profiles of organic and inorganic contaminants. Sedimentation and resuspension rates are measured. The distribution and abundance of yeasts and fungi, which degrade contaminants, are monitored. Finally, the biomagnification of contaminants in the estuarine food chain is being examined, in collaboration with researchers from Laval University, Québec.

Recent preliminary data have indicated the presence of significant sources of tetrachloroethylene and other volatile halocarbons (VHCs) along the St. Lawrence River. "Microtox" toxicity tests show low to moderate toxicity at several sites near major industrial outfalls to the river. Concentrations of the toxic trace

metal cadmium are also higher immediately downstream of Montréal.

Great Lakes Connecting Channels

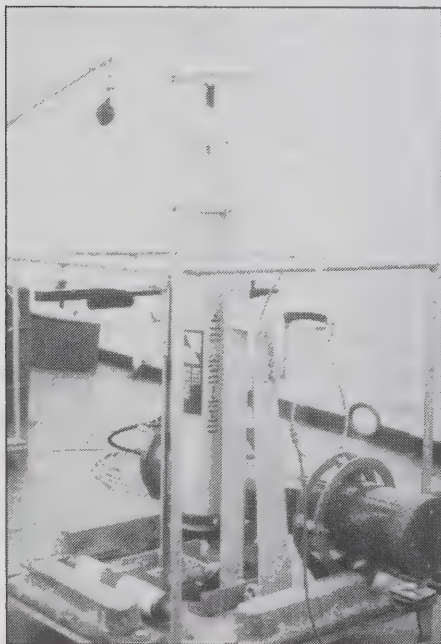
Recent research has been done in response to the requirements of the bilateral agreement on the Upper Great Lakes Connecting Channels. The episodic nature of sediment movements generated by turbulence and horizontal currents in Lake St. Clair, and the resultant effect on contaminant transport have been carefully studied. Comprehensive reports on Lake St. Clair and the Detroit River are presently being written by an international team which includes several members of the Project.

A new physical method, the flux divergence method, has been developed to account for general horizontal advection in Lake St. Clair. Field measurements and modelling were used to assess the river plume. The key factors controlling contaminant distribution in the river plume are contaminant partition coefficients and the concentrations of suspended solids.

Theoretical Concepts and Methodologies

Theoretical and applied research is required to fully interpret field data and to anticipate future problems. For these purposes, the project is studying the quantitative structure activity relationships (QSAR) of contaminants in environmental pathway and risk assessment modelling. Methodologies for trace metal analysis are also explored.

QSAR of contaminants have been investigated in the Lakes Research Branch for several years. QSAR is simply a means to calculate and predict the environmental behaviour, persistence and toxicity of a given chemical using known properties of chemically related compounds. This technique is gaining importance in the assessment of new pesticides and biologically active compounds. It is also very useful for environmental protection purposes. Environmental simulation models, such as TOXFATE developed at NWRI, need physical and chemical infor-



Smart acoustic current meter (SACM), optical transmissometer and sediment trap being prepared for mooring on the bottom of Lac St-Pierre in the St. Lawrence River to obtain data on currents and suspended sediment transport.

mation on contaminants which are frequently unknown. Reliable methods to estimate these physical and chemical properties are required because their measurement would be too costly. Recently, TOXFATE research has demonstrated its ability to predict the unusually high toxicity of certain derivatives with substituted nitrobenzene and aniline. A newer version of TOXFATE was also developed to simulate and to predict environmental pathways in Lake St. Clair and in the Toronto waterfront area.

Trace metal levels in offshore water are difficult to measure accurately. The dust particles present in the air of analytical laboratories contribute to the present uncertainty about the true metal levels in water. To remedy the situation, a special clean laboratory is being built by the Nearshore/Offshore Project for the analysis of toxic metals in water. The new

laboratory will be equipped with special air filters which will reduce the dust particles by a factor of one thousand.

Project Chief: K.L.E. Kaiser

Study Leaders: E. Halfon, P.F. Hamblin, K. Kwasniewska, C.R. Murthy, J.O. Nriagu

Project Team: K.C. Miners, D.G. Robertson, R.D. Coker M.E. Comba,

Recent Publications

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Quality Assurance Project

The use of analytical chemical data is essential in almost every aspect of aquatic environmental protection. Chemical data are used for impact assessment, the establishment of water quality criteria and standards, monitoring sewage treatment effectiveness, and water quality surveillance and regulation. Decisions that result from these data can have far-reaching impacts on society. Data accuracy, therefore, is of critical importance.

The QA Project, in the Research and Applications Branch, plans, coordinates and implements quality assurance and control programs to ensure accuracy, comparability and reliability in analytical data. It also develops Certified Reference Materials (water, sediments and biota) for use in quality assurance, analytical method research and environmental assessment studies. Other project activities include the development of management plans for quality assurance; advising on field, laboratory and data management quality control procedures; and the design and implementation of interlaboratory comparisons.

The objective of the QA project is to provide leadership for aquatic quality assurance programs in Environment Canada in order to ensure that analytical data are generally of good and comparable quality.

The interpretation of such data enables Environment Canada to provide scientific advice on conservation and abatement strategies. The long-term goal of the QA project is to assist with the development of a comprehensive national freshwater QA program.

Quality Assurance Studies

Environmental research, monitoring and assessment programs utilize large quantities of analytical chemical data from a variety of sources. These data must be of acceptable quality and comparable on a regional, national and international basis. As part of the QA project, the following programs have been developed and conducted for major national and international studies:

- A three-year multi-agency QA program for the binational Upper Great Lakes Connecting Channel Surveillance Program was completed this year. The Quality Management Work Group was generally successful in ensuring the production of quality data for the program. A total of 13 interlaboratory studies were carried out to help participating laboratories identify and correct quality control problems. Several data review reports on interlaboratory performance assessment, and a final report with recommen-

dations relevant to future multi-agency, international surveillance programs have been produced.

- A binational QA program for the Long Range Transport of Airborne Pollutants (LRTAP) Project has been operating since 1982. For this program, three large QA studies for major ions and nutrients are conducted annually. In addition, computer programs have been developed to provide information on laboratory performance and data quality. The number of laboratories participating in this program has increased considerably since 1982.

- Activities are continuing for two other national QA programs—the Federal/Provincial Water Quality Agreements and the Prairie Provinces Water Board. Monthly interlaboratory QA studies are conducted and six data summaries and six final reports are sent to participants on an annual basis. In addition, the Prairie Provinces Water Board receives an annual integrated report on laboratory performance.

- Three QA studies for the International Joint Commission's Great Lakes International Surveillance Program are designed and conducted annually for organic and inorganic parameters in water and sediment.

- A new three-year binational QA program has been specifically designed and conducted to evaluate the Eulerian acid deposition models based on comparison with field observations.

Research on Reference Materials

Certified Reference Materials (CRMs) and Reference Materials (RMs) are important tools in assessing the quality of data in both research and operational studies. As part of the QA Project, a series of RMs for water analysis and CRMs for sediment analysis have been developed. Since 1975, over 20 RMs and 5 CRMs have been developed for organic and inorganic parameters, including several of the world's first lake sediment CRMs for polynuclear aromatic hydrocarbons (PAHs), chlorobenzenes, polychlorinated biphenyls (PCBs) and selenium. These RMs and CRMs were developed to assess the performance of various international, national and interdepartmental laboratory programs and to assist laboratories in obtaining more reliable and compatible data for trace elements and toxic organic chemicals in sediments and water.

The development of CRMs for different materials and additional classes of pollutants is under way. This includes investigating existing RMs for their suitability as CRMs, as well as researching a wide range of new materials with different matrices containing different coextractives, levels of interferences and classes and levels of pollutants of interest. Ultimately, a wide variety of CRMs will be available, each yielding a different degree of analytical difficulty. Currently, a unique sediment RM is being developed for use as a multi-component and multi-class CRM for organics.

An active program to market the products and expertise of the QA Project has also begun. The first step has been to advertise the availability of the CRMS developed and prepared by the group.

Project Chief: A.S.Y. Chau

Study Leaders: K. Aspila, Y. Stokker, H. Alkema

Project Team: N. Arafat, W. Li

Recent Publications

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CLARIFICATION

In the March 1988 issue of NWRI Digest, p. 6, the article on the Contaminants Project may have left the erroneous impression that Agriculture Canada had formally announced on October 26, 1987 a limited ban on the use of tributyltin-containing antifouling paints. In fact, Agriculture Canada only announced a **proposed** ban and is presently drafting a discussion document for public consultation. After the consultations are complete, Agriculture Canada will announce its conditions of registration for tributyltin under the Pest Control Products Act.

About NWRI

Environment Canada's National Water Research Institute (NWRI) conducts a national program of original research and development in the aquatic sciences, in partnership with the international freshwater science community. The twin goals of the Institute are to advance scientific understanding of national and international water issues important to Canada and to develop knowledge and authoritative expertise on these issues that can be used by Environment Canada to influence decisions affecting the wise management of Canada's water resources.

Research at NWRI is conducted within multidisciplinary projects, each focusing on a priority issue. Projects are grouped within three branches, the Lakes Research Branch, the Rivers Research Branch, and the Research and Applications Branch. Current long-term research priorities include: toxic chemicals in the Great Lakes and the St. Lawrence River; exchange of toxic contaminants between air, water, sediments, and biota; groundwater contamination; pesticide contamination in rivers; acid rain; lake rehabilitation; and aquatic monitoring, ecotoxicology, and risk prediction methodologies.

NWRI Digest

The NWRI Digest is the quarterly public newsletter of the National Water Research Institute, Conservation and Protection, Environment Canada. Suggestions, comments and further enquiries concerning newsletter items are welcomed. Please write to the Editor, NWRI Digest, National Water Research Institute, P.O. Box 5050, Burlington, Ontario, Canada L7R 4A6.

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NWRI AND GLOBAL ATMOSPHERIC CHANGE

Chemical alteration of the earth's atmosphere is broadly acknowledged to be a critically serious problem that threatens global environmental security, including the quality and quantity of our freshwater resources. The issue is a complex one involving climate change induced by "greenhouse" gases, together with ozone depletion, acid rain and the long-range transport of persistent toxic chemicals ("toxic rain").

At last summer's landmark world conference on *The Changing Atmosphere* in Toronto, a multinational Working Group on Water Resources, co-organized by NWRI, examined the threats to global water resources.

They agreed that many of the most destructive impacts of atmospheric change will occur through disruptions to regional water systems and that these changes are taking place against a backdrop of existing water crisis in many areas of the world. The group concluded that without increased knowledge, through research, and new initiatives in national and international water resource management, global atmospheric change could threaten the very capacity of natural water systems to support sustainable human development.

NWRI's scientists share this concern and sense of urgency. Our scientific involvement in this issue can be traced back to the initiation of major research programs on the water quality impacts of acid rain and, more recently, toxic rain and climate change. Our acid rain efforts are currently focussed on the synthesis of previous research on critical processes of watershed acidification and recovery, and on aquatic resources-at-risk. The results will form part of a national LRTAP (long range transport of airborne pollutants) assessment, due for completion in 1990, in support of policy formulation and international negotiations.

With respect to toxic rain, our scientists are investigating the major factors controlling the exchange of volatile toxic compounds across the air-water interface — accurate exchange measurements are needed to quantify the impacts of toxic rain on aquatic ecosystems. A unique recirculating wind-wave flume has been constructed in the NWRI Hydraulics Laboratory for these long-term ex-

periments. The flume is completely sealed so that contaminant concentrations in water and air can be measured separately and related to wind speed, wave conditions and other factors.

The climate change program at NWRI is new and relatively small, but will grow as changes in regional climate and hydrology, which trigger ecological changes in aquatic ecosystems, become better understood. At present, computer simulation models are being developed to evaluate the long-term effects of climate warming on the physical dynamics (temperature and circulation patterns) of lakes, particularly the Laurentian Great Lakes. Proxy data on changes in past climate are also being obtained from paleoenvironmental studies of fossil invertebrates in lake sediments. Most recently, institute scientists have joined a multi-agency research project, organized by CIRAC (the Canadian Institute for Research in Atmospheric Chemistry), on the role of methane exchange from Canadian wetlands in global climate change. Lastly, to define the issue more clearly, we are planning to host a national symposium on the impacts of climate change on water quality and lake ecosystem processes within the next year.

In all of these activities, NWRI is committed to effective research and national leadership in understanding the water management implications of atmospheric change.

Ralph J. Daley
Chief
Science Liaison Division

INSIDE

- Québec Conference on River and Estuary Toxic Chemical Pollution
- Global Lake Conservation Management Conference
- New Multi-class, Multi-residue Herbicide Method
- Emergency Response to Saint-Basile-le-Grand PCB Fire
- Leeches and Chlorophenol Pollution
- Ville Mercier Aquifer Decontamination
- Athabaska River Tar Sands Project
- Northern Wetlands Project
- Hydraulics Laboratory Industrial Contracts
- Radio Immunoassay Method for Dioxins
- Windermere Basin—Physical Model Study
- International Trace Metals Conference
- Lake Restoration Project
- LRTAP Project
- Political Leaders Visit CCIW
- \$125 Million Great Lakes Action Plan
- UNEP "Global 500" Award

RESEARCH NEWS

Global Lake Conservation and Management Conference

Drs. R.A. Vollenweider and R.J. Allan of NWRI delivered plenary speeches at the "Third International Conference on the Conservation and Management of Lakes", held in Keszthely, Hungary, in September. Dr. Vollenweider reviewed the progress in understanding and controlling eutrophication, while Dr. Allan provided an assessment of the extent and trends of toxic chemical contamination in major lakes around the world. Along with three other NWRI papers, the plenary lectures affirmed the advanced level of applied research and water management integration in Canada. These conferences are held every two years under the auspices of the International Lake Environment Committee (ILEC) Foundation, based in Japan.

New Multi-class, Multi-residue Herbicide Method

In response to a request from Inland Water Directorate's Water Quality Branch, Western and Northern Region, a multi-class, multi-residue method for the quantitative analysis of ten acid and six neutral herbicides in sediments has been developed by Y. Stokker, Research and Applications Branch. The extensive use of these herbicides in Western Canada has given the regional laboratories cause for concern because of the known toxicity and persistence of both the parent herbicides and their metabolites. Large numbers of samples have to be processed in support of regional surveillance and monitoring programs. Considerable sampling and analysis time is saved using the new method because the sample is extracted once and the extract analyzed for both acid-type herbicides (phenoxyalkanoic acids) and the neutral type herbicides (carbamates, ureas and esters).

Reference: Stokker, Y.D. 1988. Method for the analysis of acid and neutral herbicides in sediments. NWRI Contribution No. 88-67.

Emergency Response to Saint-Basile-le-Grand PCB Fire

On Tuesday, August 23, 1988, a PCB storage warehouse in Saint-Basile-le-Grand, Quebec, erupted into flames, forcing the evacuation of more than 3000 area residents because of possible contamination of the surrounding area. To monitor contamination levels, samples from homes and surrounding soil and water were collected and analyzed by federal, provincial and private sector laboratories.

Staff from the Analytical Chemistry and the Quality Assurance projects, Research and Applications Branch, worked around the clock in cooperation with the National Water Quality Laboratory to provide a coordinated analytical response to the Saint-Basile-le-Grand PCB fire. Several hundred hours of effort were contributed by scientists to this urgent and sensitive situation. Staff undertook the preparation, cleanup and analysis of water, sedi-

ment and swab samples for PCBs, dioxins and furans, as well as the design and implementation of an appropriate quality assurance program, including the use of certified PCB sediment reference materials.

The Clean and Hazardous Chemical Laboratory of the Research and Applications Branch was totally committed to determining the extent of dioxin/furan formation and the associated level of contamination, as a result of the combustion of the PCBs. Selected soil samples from the fire site were collected and processed for use in an interlaboratory quality assurance (QA) study, designed and conducted by the QA group. The study ensured that critically needed comparability was established among the various laboratories generating the analytical data on levels of contamination.

Leeches and Chlorophenol Pollution

Scientists of the Rivers Research Branch and the Ontario Ministry of the Environment (MOE) have successfully used leeches to assess the impact of chlorophenols in waters. The use of chlorophenols as slimicides in pulp and paper mills was suspended in 1981, but chlorophenols are still produced during the pulp bleaching process and released to the environment. They are also used in large quantity for short- and long-term preservation of lumber.

In their field trials, J.L. Metcalfe (NWRI) and A. Hayton (MOE) exposed caged leeches above and below a pulp and paper mill complex on the Rainy River (Northwestern Ontario) and near a wood preserving plant in Thunder Bay Harbour. Leeches were selected because earlier field and laboratory studies at NWRI revealed that leeches have unusually high bioconcentration capacities and slow elimination rates for chlorophenols. The study found that concentrations of chlorophenols were elevated above pre-expo-

sure levels in leeches caged over 100 km downstream of the pulp mill complex, even though chlorophenols could not be detected in water or suspended solids. Tissue residues of chlorophenols in caged leeches also provided information on the origin, distribution and bioavailability of chlorophenols discharged from the wood preserving plant on Thunder Bay Harbour.

As a result of this study, MOE's Water Resources Branch has started to use leeches in routine monitoring whenever chlorophenol pollution is suspected. This represents a successful transfer of technology from NWRI to a provincial agency.

References

Metcalfe, J.L., M.E. Fox and J.H. Carey. 1988. Freshwater leeches (*Hirudinea*) as a screening tool for detecting organic contaminants in the environment. NWRI Contribution No. 88-13.

Metcalfe, J.L. and A. Hayton. 1988. Comparison of leeches and mussels as biomonitors for chlorophenol pollution. NWRI Contribution No. 88-90.

Ville Mercier Aquifer Decontamination

Ville Mercier, located 20 km south of Montreal, has had serious aquifer contamination since the early seventies when large quantities of industrial waste were discharged into an abandoned gravel pit. Contaminants present in the landfill site include, among others, volatile organics, chlorinated organic solvents and traces of PCBs, PAHs and phenols.

The federal government, under Supply and Services Canada's Unsolicited Proposal Program, recently awarded a contract to a consortium composed of SNC Inc. and Laval and Sherbrooke universities to decontaminate the Ville Mercier aquifer. The project involves a detailed hydrogeological investigation of the site and construction of a pilot water treatment plant to be run in parallel with an existing plant that has proven largely ineffective in the removal of chlorinated organics. The Wastewater Technology Centre at CCIW will serve as Scientific Authority for the project, and Drs. R.E. Jackson and S. Lesage of the Groundwater Contamination Project, Rivers Research Branch, will oversee the hydrogeological work of Professor P. Gélinas and the analytical work of Dr. C. Roy (both at Laval University). NWRI and Laval University will also collaborate on the characterization and initial analysis of water pumped from the landfill site and NWRI will conduct a quality assurance program for the analyses carried out at Laval.

Athabasca River Tar Sands Project

The Rivers Research Branch recently received approval from the interdepartmental Panel on Energy R&D (PERD) to commence a major four-year study on aquatic effluents arising from tar sands and heavy oil operations on the Athabasca River. The collaborative study with Environmental Protection, Western and Northern Region (W&NR), was developed in response to regional priorities, and will focus on the pathways, fate and effects of effluents. A major goal is the development of predictive models for effluent assessment and ambient monitoring in the oil and gas industry. The study will be managed jointly by W&NR and NWRI staff.

Northern Wetlands Project

Methane is a "green house" gas involved in global climate change. The concentration of methane has doubled since the nineteenth century and is presently increasing at 1% per year. The reasons for this increase are poorly understood, but some estimates support that anaerobic processes in wetlands could account for 15 to 40% of the emissions. Because Canada's Hudson Bay Lowlands contain one of the largest wetland areas in the world, they will be the focus of a major interdisciplinary and inter-agency study, developed by the Canadian Institute for Research in Atmospheric Chemistry (CIRAC), to quantify their contribution to the methane cycle. Dr. W.A. Glooschenko, Lakes Research Branch, has been appointed Project Coordinator for this Northern Wetlands Project which includes participation by the Atmospheric Environment Service, Agriculture Canada, the National Research Council of Canada, Ontario Hydro and the universities of Guelph, McMaster, Western Ontario, Manitoba, McGill, Saskatchewan and York. Significant involvement by NWRI's Air/Water Interactions Project is also expected in research studies on the organic carbon and sulphur cycles. The project will establish three field research sites as well as an extensive aerial surveillance project in collaboration with U.S. scientists from NASA. A major field program is planned for 1990 with data analysis continuing through 1991-1992. For further details contact Dr. W.A. Glooschenko at (416) 336-4786.

Québec Conference on River and Estuary Toxic Chemical Pollution

The international symposium on the "Fate and Effects of Toxic Chemicals in Large Rivers and Their Estuaries", held in Québec last October, proved to be an important event in the melding of environmental research interests and public concern over the health of our large rivers, particularly the St. Lawrence. The conference was organized by Dr. R.J. Allan, Lakes Research Branch, and Dr. P.G.C. Campbell, INRS-Eau, who invited front-line scientists from 20 countries to present recent research results and overviews of river pollution issues in their regions.

A significant number of the papers concerned the St. Lawrence system. Over a third of these were authored or co-authored by NWRI researchers. Participation by senior federal and provincial politicians (The Hon. Lucien Bouchard, Secretary of State of Canada, and The Hon. Clifford Lincoln, Quebec Minister of Environment), as well as public concern for the health of the St. Lawrence and its estuary, produced intensive national and local media coverage. A major theme of the researchers' comments was the need to design interdisciplinary studies that permit both freshwater and marine scientists to work together in the most complex aquatic ecosystem in the world: the large river/estuary environment.

Hydraulics Laboratory Industrial Contracts

- A cost-recovery contract to determine the effect of down-sizing a precast erosion control product known as "mini-slabs" has been completed by P. Engel of the Hydraulics Laboratory, Research and Applications Branch, for Lafarge Construction Materials (Calgary, Alberta). "Mini-slabs" are slotted concrete blocks (430 mm x 430 mm x 100 mm), which are linked together to form a matrix on drainage channel surfaces subject to erosion. The effectiveness of the interlocking matrix was assessed by determining the mean flow velocity in open channel flow which the blocks could withstand without failing.

- Sandwell Swan Wooster Inc. was retained to design an inner rip-rap breakwa-

ter for a new marine project at Port Colborne, Ontario. The marina breakwater would be protected from Lake Erie waves by an existing outer harbour breakwater. Under design conditions, however, the outer breakwater is overtopped and wave energy is transmitted toward the inner harbour and marina. Through a cost-recovery contract, the Hydraulics Laboratory determined the design wave and investigated the design cross-section of the marina breakwater for Sandwell Swan Wooster Inc. A model of typical breakwater sections of the outer breakwater was constructed in the wind-wave flume and used to successfully characterize both the wave energy that overtops the breakwater and the response of the inner rip-rap breakwater to overtopping.

Radio Immunoassay Method for Dioxins

A modified radio-immunoassay (RIA) method for the rapid detection of polychlorinated dibenzo-p-dioxins in environmental samples has been developed by Dr. J.P. Sherry, Research and Applications Branch. The RIA procedure is a rapid screening test that can improve analytical efficiency and reduce costs for determining dioxins in environmental samples. The assay is relatively sensitive, reproducible and amenable to automation, and should prove useful in environmental surveillance and monitoring programs. A detailed description of the method has been prepared as an aid to analysts implementing the technique for routine laboratory use.

Reference: Sherry, J.P., J. Apsimon, L. Colier, B.K. Afghan and P.W. Albro. 1988. Radioimmunoassay for the detection of polychlorinated dibenzo-p-dioxins in environmental samples: method description. NWRI Contribution No. 88-73.

Windermere Basin—Physical Model Study

Windermere Basin, located in the southeast corner of Hamilton Harbour, evolved into an enclosed body of water due to landfill at the southern end of the harbour between 1954 and 1972. Subsequent accumulation of solids from Redhill Creek and other sources resulted in exposed, contaminated mud flats and poor aesthetic qualities. After considerable

International Trace Metals Conference

The first "International Conference on Trace Metals in Lakes" was held at McMaster University, Hamilton, from August 14 to 18. The conference, organized by Drs. J.O. Nriagu and K.R. Lum of Lakes Research Branch, drew over 150 participants from 20 countries. It was sponsored by Environment Canada, the Ontario Ministry of the Environment, U.S. EPA, McMaster University, the International Joint Commission, the Canadian Society for Chemistry (The Chemical Institute of Canada) and the Conservation Foundation, Washington, D.C. The sessions covered a broad range of trace metal issues in lakes, including the ecotoxicology of metal mixtures, acid rain effects on mobilization of metals, trace metal speciation, bioavailability, bioaccumulation, cycling and historical loading trends.

The meeting not only drew attention to the worldwide nature of lacustrine contamination by toxic metals, but highlighted the fact that most freshwater research laboratories are ill-equipped to measure accurately the low levels of metals in lake ecosystems. About a decade ago, the use of "clean laboratory" methods established a close linkage between nutrient and trace metal cycles and led to a major revolution in the understanding of the marine cycle of toxic metals. The few "clean laboratory" data presented at the conference point to a similar close linkage. It is thus likely that the current dogma on the behaviour and fate of metal pollutants in lakes will soon be revised. If so, the conference may prove to have been a watershed in the basic understanding of trace metals in freshwater ecosystems.

study, it was decided to implement a \$4.5 million partial dredging and filling scheme to improve both the aesthetic and functional characteristics of the basin. The rehabilitation plan involves the dredging of contaminated sediment, with disposal behind berms and landfill at the eastern end of the basin.

At the request of Mar-Land Engineering Ltd., agents for the Hamilton Harbour Commission, P. Engel of the Hydraulics Laboratory, Research and Applications Branch, conducted a physical hydraulic model study related to the Windermere Basin rehabilitation project. The study

determined the hydraulic properties of the re-designed basin. Several flow conditioning schemes were evaluated, including spur dikes, a weir at the basin outflow, a flow deflector at the entrance of the basin and a sediment trap.

The aim of the study was to find the most effective way to minimize the transport of naturally suspended particles from Redhill Creek and other sources into the open harbour. Testing concentrated therefore on finding the optimum placement of spur dikes in order to help increase retention time through control of the path of flow containing fine suspended particles.

S T A F F N E W S

Dr. W.G. Booty has recently joined the LRTAP Project, Rivers Research Branch, as part of the research revitalization program. Dr. Booty will work on reviewing and verifying several acid rain models for the Canadian LRTAP assessment due in 1990. He will also be developing and applying toxic chemical fate and effect models and will be involved in Turkey Lakes watershed studies. Before coming to NWRI, Dr. Booty was Assistant Professor in the Department of Environmental Engineering at Clarkson University, Postdam, N.Y.

Dr. S.A. Daniels has joined the Analytical Chemistry Project team, Research and

Applications Branch, through the research revitalization program. Dr. Daniels obtained his Ph.D. from the University of Waterloo and has research experience in analytical detector systems and chemical separation techniques. His research and development program will focus on the interface between analytical chemistry and chemical toxicology.

Dr. J. Doering has begun an NSERC post-doctoral fellowship in the Research and Applications Branch. Dr. Doering recently graduated in physical oceanography from Dalhousie University. While at NWRI, he will be working on the analysis of Lake Ontario wave data from previ-

ous experiments on shoaling waves to determine the joint distribution of wave heights and periods at shoaling water depths. He will also be involved with laboratory tests of the same phenomenon.

Dr. M. Servos, who recently received his Doctorate at the University of Manitoba, has joined the Air/Water Interactions Project of Lakes Research Branch. His thesis, entitled "Fate and bioavailability of polychlorinated dibenzo-p-dioxins in aquatic environments", was undertaken at the Experimental Lakes Area of the Department of Fisheries and Oceans in Northwestern Ontario. Dr. Servos' re-

search at NWRI will focus on the aquatic processes which modify the exchange of volatile and semi-volatile toxic organic compounds at the air/water interface.

Dr. K.E. Day, Rivers Research Branch, has been appointed as an Associate

Member of the Faculty of Graduate Studies, University of Guelph, Ontario.

Dr. E.D. Ongley, Director of the Rivers Research Branch, has recently been elected to the position of Visiting Professor in the College of Medicine at Yonsei

University, in Seoul, Korea. This is in recognition of his collaboration with Dr. P.R. Chung, Director of the Institute of Tropical Medicine, in the field of biological and chemical assessment of water quality in Korean rivers.

PROJECT FOCUS

Lake Restoration Project

Pollution issues such as eutrophication, metal contamination and persistent toxic chemicals are ongoing even though there has been much work and legislation to control loadings. Now that the first steps in pollution control have been accomplished, the remaining actions are more expensive and require information specific to each situation. In addition, there are emerging *in situ* technologies for ameliorating the effects of past pollution and improving naturally poor quality water. The goal of research in the Lakes Restoration Project is to provide multidisciplinary expertise, interpretive advice, scientific data and techniques needed for practical lake restoration and pollution management.

Great Lakes area

To date, the primary success of the Canada/U.S. Great Lakes Water Quality Agreement has been to improve and stabilize water quality in the offshore areas of the lakes. The remaining pollution, although much reduced, is introduced close to shore and can still be a problem where there is insufficient dilution. The 17 worst areas, which are typically embayments and harbours, have been termed "Areas of Concern", for which the federal and provincial governments are preparing Remedial Action Plans (RAPs). In these confined areas, the historic accumulations of metal and organic pollutants can contaminate the ecosystem and its food chain. Remedies may be as simple as allowing the contamination to become naturally buried or as costly as complete removal by dredging. In almost every case, however, some reduction in loading is still needed. The Lakes Restoration Project, Lakes Research Branch, is a major contributor of the expertise and research required in the RAP process for critical assessments of management op-

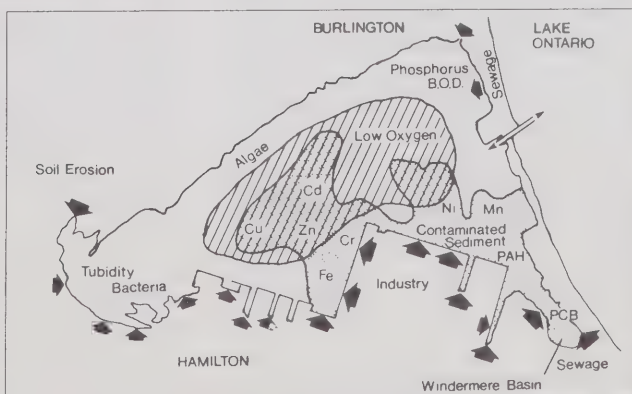
tions to clean up and preserve these aquatic ecosystems.

For example, the low oxygen problem during summer in the deep waters of Hamilton Harbour was researched with a water quality profiling system developed at NWRI. Consumption rates in bottles were five to ten times the actual oxygen depletion rate observed in the harbour. The large oxygen input from the ship canal may be matched by the initial oxygen demand caused by ammonia loading from sewage treatment plants discharging to the harbour. Our experiments support the hypothesis that oxygen conditions may be significantly improved by ammonia controls. The technique of bubbling pure oxygen was investigated by temporarily installing a diffuser apparatus in the harbour. Oxygenation efficiency of the apparatus was found to depend on the type and spacing of the diffusers. The technique is being further assessed with a relatively large installation at Amisk Lake (Alberta), in cooperation with the University of Alberta.

The interaction of contaminated sediment with the water column is also being assessed through several simultaneous studies. In one study, sediment traps showed that resuspension can cause a redistribution of contaminated sediment. Samples from sediment traps are being analyzed to determine whether contaminant deposits are being buried by cleaner materials. In a second study, the toxicity of sediment extracts was tested using bioassays to determine which sites would have the highest priority for removal or treatment. Various *in situ* chemical treatments of high-toxicity sediments are being evaluated for their neutralization performance and

possible side effects. The project is also developing sonar techniques for determining the thickness and volume of contaminated sediment deposits so the magnitude of these problems can be assessed. Initial estimates are that the modern (contaminated) sediment deposits are only 34-cm thick. In the third study, industrial iron particles and high concentrations of ammonia were observed in plumes of harbour water in Lake Ontario, which suggested that the harbour is at times inefficient as a settling trap or dilution chamber.

The problem of high turbidity in the Cootes Paradise area of Hamilton Harbour is also being studied. Experiments have shown that the main cause of turbidity is resuspension of bottom sediments both by wind and by large populations of carp. Extension of this work to the harbour will be particularly important for the RAP, because large reductions in turbidity are needed before noticeable improvements in clarity are achieved. Project staff summarized findings and contributed major portions of the discussion document on the "Goals, Problems and Options for Hamilton Harbour's Remedial Action Plan". Similar research activities by our project are ongoing in support of the Bay of Quinte RAP where phosphorus regeneration from sediments is a main concern. Iron-phosphorus relationships



Hamilton Harbour: The pollution effects of industrial discharge, sewage treatment plants and sewer outflows.

in particulate material entering the bay compared to the relationship in bottom sediments are being assessed.

Small lakes

Many small, naturally eutrophic lakes have impaired use due to large populations of unsightly blue-green algae. In some areas, surface runoff is collected in dugout ponds as a source of drinking water for people and livestock. Most of these dugouts have algae problems. Because these algae even produce toxins which can harm livestock, an ecologically sound algal control method is needed. Our experiments show that the traditional practice of copper sulphate treatments to control algae produces residual toxicity to other biota and disrupts the natural sulphur cycle by poisoning sediment bacteria.

In cooperation with the University of Alberta, project scientists are investigating the use of lime to augment the natural precipitation reaction of calcium and phosphorus. Addition of lime to Figure Eight Lake (Alberta) and to drinking water dugout ponds increased the precipitation of nutrients and produced cleaner water. In one lake, the sediments contained enough phosphorus that it could have

been sold as low grade fertilizer, yet the water was very clear. Using Mössbauer spectrometry we found that there is a significant iron source in groundwater flowing to the lake. This iron-rich water is responsible for precipitating most of the phosphorus which would otherwise be released from the sediments and cause algal blooms. For the majority of lakes which recycle phosphorus from the bottom, we are investigating economical ways to remove the nutrient-rich sediments.

Excessive aquatic weed growths, particularly Eurasian milfoil, limit the use of the littoral zone in many lakes and rivers across the nation. To help prevent further invasions of exotics, we provide expertise and advice on the importation of deleterious aquatic plants. The project research has focused on better techniques for mechanical removal of plant infestations and on the ecological implications of chemical control. There have been significant declines of some milfoil populations in Southern Ontario. Our investigations have correlated these declines with the appearance of aquatic moth larvae which specialize in eating milfoil.

Project Chief: M.N. Charlton

Study Leaders: M. Fox, M. Hanna, P.G. Manning, T. Mayer, T.P. Murphy, D.S. Painter, N.A. Rukavina

Project Team: W.G. Booth, L.L. Kalas, P.A.L. Thiessen.

Recent publications

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LRTAP Project

Acid rain is caused by emissions of sulphur dioxide and nitrogen oxides. Once released into the atmosphere, these substances can be carried long distances by prevailing winds and return to earth as acidic rain, snow, fog, or dust. When the environment cannot neutralize the acid that is being deposited, damage occurs. It is estimated that the national resource base currently at risk sustains approximately 8% of Canada's gross national product. More than 300,000 lakes are vulnerable and some 14,000 have already been acidified. Half the lakes and rivers located in sensitive areas (Muskoka-Haliburton in Ontario, southern Quebec and southern Nova Scotia), where sulphate deposition rates exceed acceptable limits, are already deteriorating. The Long Range Transport of Airborne Pollutants (LRTAP) Project of the Rivers Research Branch deals mainly with the aquatic effects of those pollutants.

The current activities of the LRTAP Project are largely in response to the needs of

the upcoming national LRTAP "acid rain" assessment due to be completed in early 1990. Project members are involved in reviewing research results, participating in working groups, providing scientific leadership and contributing to such research priorities as sulphur cycling and natural organic acidity. Research into hydrological and chemical interactions provides input to modelling activities through which emission-impact scenarios can be assessed. The project is also responsible for providing national leadership in the science of LRTAP monitoring and assessment to permit evaluation of large-scale patterns of risk to Canadian freshwater resources from acid rain, and to provide expert opinion on international research activities which may impact upon Canadian negotiating positions.

Turkey Lakes watershed study

The Turkey Lakes Watershed, located about 50 km north of Sault Ste. Marie, Ontario, is the primary experimental site at which NWRI scientists have conducted their research on acid rain since 1980. A 21-paper special review volume on the Turkey Lakes Watershed Study was

published recently (*Canadian Journal of Fisheries & Aquatic Sciences*, Vol. 45, Suppl. No. 1). It spans the entire range of work that has been conducted, including aquatic chemistry and biology, forestry, and predictive modelling. The processes controlling the hydrological and chemical fluxes associated with spring melt, mass balance studies for ionic species, and aluminum geochemistry were also described at international conferences or in review papers.

Sulphur cycling

Sulphur isotopic data suggest that large amounts of sulphur are released during summer from biogenic sources such as bogs, marshes and wetlands that cover large areas of Canada. In the first measurement of its kind, large amounts of dimethyl sulphide (DMS) were shown to be produced and released from such ecosystems. Calculations suggest that such sources can contribute up to 20% of the airborne sulphur in rural and remote areas of Canada. DMS is rapidly oxidized in the atmosphere by hydroxyl and nitrate ions to sulphur dioxide and methane sulphonc acid (MSA). MSA is thus a marker that

can be used to assess the magnitude of the biogenic contribution to the atmospheric sulphur burden. The combined use of isotopic and MSA techniques is a potentially powerful tool in acid rain research.

Organic acidity

The aquatic effects of acidic deposition are often complicated by naturally produced acidity from organic matter such as peat and sphagnum. In Nova Scotia, many rivers are affected by such organic acidity and show brownish-coloured waters. While they may be subject to similar amounts of acidic deposition, these rivers exhibit different levels of pH. Extensive research has been carried out by NWRI scientists on these rivers. Experimental results, aided by modelling and statistical methods, attribute the difference in pH levels to the interactions between organic and inorganic acidity and to the different kinds of organic matter present.

Many of these research results at NWRI were recently presented at an international scientific conference on organic acid studies (Kejimikujik Conference '88). They will be published in a special review volume mainly devoted to the Kejimikujik Watershed Study, a study parallel to that of the Turkey Lakes Watershed.

Long-term versus episodic events

Sulphate ions accumulating in snowpack can cause stream pH to drop significantly when they are released during snowmelt. The impact is short in duration, lasting for weeks at most. On the other hand, depending on the soil buffering and weathering rates, the yearly mean pH level will not show large changes until decades or centuries after sulphur emission control or other measures such as liming are implemented. In both cases, hydrogeochemi-

cal models provide insight into the basin responses to control programs. At NWRI, a number of such models have been tested under different management scenarios and probabilities of snowmelt occurrences.

Regional assessment

Regionalization of acidification impact models may provide a more objective means for assessing alternative acid rain control strategies. A prototype expert system, RAISON (regional analysis by intelligent systems on a microcomputer), was developed and shown to improve the performance of individual models. In a normal review of over 100 studies in the U.S. and Canada, a U.S. EPA expert research panel on modelling characterized the RAISON study as a "clear, relevant and realistic" approach. The system provides a highly flexible framework within which a wide variety of geographically based environmental problems can be effectively evaluated.

In an effort to integrate scientific information on atmospheric, terrestrial and aquatic linkages, RAISON has been used to collate regional data from Eastern Canada, where impact of acid rain is most acute. Predictions of the aquatic effects based on several management strategies are made by the expert systems approach.

Resources-at-risk

An improved and more acceptable functional relationship between the aquatic and terrestrial regime factors was applied to all the watersheds in the Province of Quebec south of latitude 52° N. The relationship permits evaluation of aquatic resources at risk in the cases where terrestrial data exist, but aquatic data are insufficient. Risk estimates indicate 4.5%

of the lakes are in critical condition, and an additional 48.5% are in a very sensitive and susceptible condition. This empirical technique is currently being extended to other regions.

Monitoring and statistical evaluation

Canada already has a sulphur emission program in place. To determine whether this program is effective will require further information and data collection based on an adequate monitoring network. Advanced statistical methods are designed to evaluate existing LRTAP monitoring data and to recommend cost-effective sampling strategies based on the current control program or other proposed control measures.

Project Chief: D.C.L. Lam

Study Leaders: A.G. Bobba, W.G. Booty, R.A. Bourbonniere, A.H. El-Shaarawi, A.S. Fraser, R.G. Semkin

Project Team: J.L. Jones, F. Norouzian, R. Neureuther, M.D. Seymour

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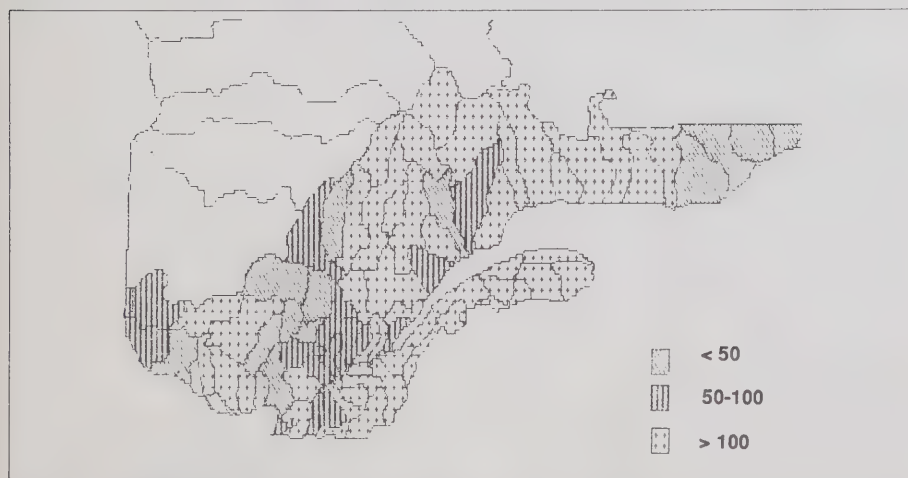
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Predicted average acid neutralization capacity ($\mu\text{eq/L}$) for 91 watersheds in southern Quebec using the RAISON expert system under present loading condition.

PUBLIC AWARENESS

Political Leaders Visit CCIW During Federal Election Campaign

On October 19, Prime Minister Brian Mulroney and his wife visited CCIW. Mr. Mulroney toured the NWRI Hydraulics Laboratory and the Wastewater Technology Centre, viewing a number of research demonstrations and meeting staff. The following week NDP leader Ed Broadbent visited the Wastewater Technology Centre.



The Rt. Hon. Brian Mulroney during his visit of the Hydraulics Laboratory.

PM Announces \$125 Million for Great Lakes Cleanup

While making an address in Hamilton on October 19, the Prime Minister announced a \$125 million Great Lakes Action Plan. The fund will be used to meet Canadian obligations under the recently revised International Great Lakes Water Quality Agreement. Seventy-five million dollars will be devoted to clean up 17 environmental "hot spots" and \$50 million will go towards developing the scientific and technical knowledge necessary to maintain the quality of the Great Lakes and prevent future pollution.

UNEP "Global 500" Award

On the occasion of the World Environment Day, the United Nations Environment Program (UNEP) named Dr. Richard A. Vollenweider, NWRI's retired Senior Scientist, to its "Global 500 Roll of Honour". This award is in recognition of Dr. Vollenweider's outstanding work in helping to protect and improve the environment. Commenting on Dr. Vollenweider's distinguished career, D.L. Egar, Executive Director, NWRI, said that "although Dr. Vollenweider has officially retired from the Public Service of Canada, his accomplishments and his dedication to improving the world's water resources will continue to inspire Canadians and others around the world".

St. Lawrence River Video

G. Sivell, NWRI Communications Officer, led a field team that obtained over 20 hours of broadcast-quality footage on the St. Lawrence River and river basin for use in developing future information videos and documentaries. The project is jointly funded by NWRI and the Quebec Region of C&P. Portions of the video have already been used for TV news coverage by the CBC French and English networks, Montreal. NWRI is currently discussing with TV Ontario and Alberta's Access Network the possibility of co-producing

TV documentaries on the environmental status of the river and on the research conducted by NWRI in support of Environment Canada's "Plan Saint-Laurent" to restore the water quality of the river.

COMING EVENTS

March 28-29, 1989. Workshop on Cause-Effect Linkages. This workshop will examine the scientific basis for inferring causality between toxic contaminants and health effects in fish, birds and mammals (including man) in the Great Lakes. A variety of case histories where contaminant-stress linkages have been established will be reviewed. The workshop will be held by the IJC Council of Great Lakes Research Managers. For further information, contact Dr. M. Gilbertson, (519)256-7821.

April 4-7, 1989. International Conference on Statistical Methods for the Environmental Sciences. Dr. A. El-Shaarawi, NWRI, and Dr. I. MacNeill of the University of Western Ontario are co-chairmen of this conference to be held in Cairo, Egypt. The meeting will include such topics as water and air quality, regulation and control, waste management, transboundary pollution, health aspects of pollution, risk analysis, monitoring and quality control. For further information, contact Dr. Abdel El-Shaarawi, (416)336-4584.

About NWRI

Environment Canada's National Water Research Institute (NWRI) conducts a national program of original research and development in the aquatic sciences, in partnership with the international freshwater science community. The twin goals of the Institute are to advance scientific understanding of national and international water issues important to Canada and to develop knowledge and authoritative expertise on these issues that can be used by Environment Canada to influence decisions affecting the wise management of Canada's water resources.

Research at NWRI is conducted within multidisciplinary projects, each focusing on a priority issue. Projects are grouped within three branches, the Lakes Research Branch, the Rivers Research Branch, and the Research and Applications Branch. Current long-term research priorities include: toxic chemicals in the Great Lakes and the St. Lawrence River; exchange of toxic contaminants between air, water, sediments, and biota; groundwater contamination; pesticide contamination in rivers; acid rain; lake rehabilitation; and aquatic monitoring, ecotoxicology, and risk prediction methodologies.

NWRI Digest

The NWRI Digest is the quarterly public newsletter of the National Water Research Institute, Conservation and Protection, Environment Canada. Suggestions, comments and further enquiries concerning newsletter items are welcomed. Please write to the Editor, NWRI Digest, National Water Research Institute, P.O. Box 5050, Burlington, Ontario, Canada L7R 4A6.

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NWRI HOSTS CEPA SCIENCE FORUM

The Canadian Environmental Protection Act (CEPA), which became law in June 1988, replaces or complements previous federal legislation and is now the primary Act for the nationwide management of toxic substances. The Act guarantees Canadians the right of protection from the risks associated with the use of chemicals and their release to the environment. CEPA takes a "life cycle" approach to ensure that each toxic substance is controlled at those points where it poses risk to the environment or human health. The Act goes far beyond the traditional approach of "react and cure" to one of "anticipate and prevent". CEPA is built on an ecosystem perspective, placing environmental considerations on an equal footing with public health considerations.

NWRI undertook to host a "Priority Substances Science Forum" to address the science needs of the priority substance assessments required as part of CEPA. The specific objectives of the multi-stakeholder, multidisciplinary sessions were fourfold: (1) to provide information on CEPA, its Priority Substances List (PSL), and the assessment process; (2) to present the federal five-year schedule for addressing the PSL; (3) to examine the research and information needed to complete the assessments; and (4) to facilitate coordination of the science community and funding agencies.

The Forum, which was held at the Canada Centre for Inland Waters, February 21-23, 1989, brought together research scientists and science managers from federal, provincial and municipal governments, universities, the private sector, funding agencies and public interest groups.

The overall conclusion from the two days of discussion was that the expertise to address the science requirements of CEPA exists in Canada. However, strong leadership must be provided to draw together the consortium of scientific stakeholders from inside and outside government to address the research requirement of the Act. To this end, the CEPA management framework and implementation plan should include an explicit five-year science program that is integrated with, but operated separately from, the other elements of CEPA (assessment, control and regulation).

Suggestions to facilitate development of the CEPA science plan included designation of a single federal

"Responsibility Centre for CEPA Science" and the creation of a "National CEPA Science Stakeholders Network". For operational flexibility, the Science Centre should be located at an existing federal research institute and should be provided with a dedicated, multi-year budget and administrative support.

The mission of the Centre would be to meet the research needs arising from the assessment, regulation, monitoring, inspection and enforcement activities of the federal Act and its provincial counterparts (e.g., MISA in Ontario). This would be accomplished through the operation of a nationwide network of experts from the Canadian research community. The Centre would also establish links internationally where work relevant to CEPA science is being done (e.g., the Organization for Economic Co-operation and Development). It is important that the science effort focus on matters that are uniquely important in Canadian ecosystems, i.e., the presence, transformation and effects of toxic chemicals in the Canadian environment. Chemical toxicology and other more general data would then be obtained from international sources.

There was also a general consensus that the CEPA science forum should be continued as an "Annual Meeting of the National CEPA Science Stakeholders Network". A full report of the proceedings of the forum will be completed within two months and distributed to all participants and other interested parties.

Dr. J. Lawrence
Director
Research and Applications
Branch

INSIDE

- NWRI Sustainable Development Symposium
- St. Lawrence Estuary Research
- National Laboratory Association
- Unesco Handbook of Comparative Hydrology
- Transport of Chlorinated Contaminants in the St. Clair and Detroit Rivers
- Certified Reference Materials Brochure
- Toxic Dye/Particle Interactions in the Yamaska River, Quebec
- Waves and Wave Forecasting
- Historic Variations in Great Lakes Water Levels
- New Analytical Methods
- NWRI/IJC Workshop on Contaminated Sediments
- Nutrient-Contaminant Interactions Project
- River Modelling Project

RESEARCH NEWS

St. Lawrence Estuary Research

The Upper Estuary of the St. Lawrence River, between Quebec City and the Saguenay Fjord, is a complex area where dissolved and particulate materials interact within a unique "turbidity zone" in the water column. This zone is maintained by estuarine circulation and by tidal pumping, both of which provide energy to maintain particles in suspension. Recent research by the Nearshore/Offshore Interactions Project, Lakes Research Branch, has shown that variations in suspended sediment concentrations can be simulated by a one-dimensional suspended sediment model. The model could prove useful in predicting the residence time of

contaminants in the maximum turbidity zone and their eventual transport and fate in the estuary.

References

Hamblin, P.F., K.R. Lum, M.E. Comba and K.L.E. Kaiser. 1988. Observations of suspended sediment flux over a tidal cycle in the region of the turbidity maximum of the Upper St. Lawrence River Estuary. *In: Hydrodynamics and Sediment Dynamics of Tidal Inlets*, D.G. Aubrey and L. Weishar (Eds.), Springer-Verlag New York, Inc., pp. 245-256.

Hamblin, P.F. 1988. Observations and model of sediment transport near the turbidity maximum of the Upper St. Lawrence Estuary. NWRI Contribution No. 88-42.

National Laboratory Association

A Canadian network of credible analytical laboratories is essential to meet expected increases in analytical workload resulting from CEPA, MISA and other environmental programs. On behalf of NWRI, The Rawson Academy of Aquatic Science examined the feasibility of forming an independent, self-regulating association of Canadian environmental analytical laboratories. They surveyed representative groups from government, industry and universities on the value of such an association and on its appropriateness as a vehicle to introduce effective quality assurance/quality control programs. The response was very positive, with a general consensus that such an association would benefit both the laboratory industry and clients. Also, because of recent U.S. EPA experiences with QA/QC programs in industry and uncertainty about the potential effects of the Canada-U.S. Free Trade Agreement, it was felt that there was some urgency to establish a national laboratory association in Canada.

The implementation phase of the project is also being facilitated by The Rawson Academy. A laboratory association called the "Canadian Association of Environmental Analytical Laboratories" (CAEAL) has been formed. An interim Board of Directors has been established, consisting of three private sector representa-

tives, three provincial government representatives and one federal government representative. The interim Board is chaired by Dr. J. Lawrence, Director of NWRI's Research and Applications Branch. Secretariat support is being provided by The Rawson Academy.

The interim Board of Directors held its inaugural meeting on January 23, 1989. One of the first priorities of the Board will be to negotiate with the Standards Council of Canada for their services in developing and implementing a laboratory accreditation scheme for the member laboratories, and to assist the Standards Council in obtaining the necessary Treasury Board funding. A working group has been established to address the accreditation requirements of the association in preparation for negotiations with the Standards Council.

Other priority areas for the Board will be the establishment of the association's membership, the refinement of draft bylaws and the formal incorporation of the association.

Regional information sessions for potential members have been held in St. John's, Halifax, Québec, Toronto, Calgary and Vancouver. The response at these meetings has been very encouraging.

UNESCO Handbook of Comparative Hydrology

The conventional approach to hydrology has focused on the water-land interface without consideration of sociological and ecological implications. Recognizing such shortcomings, the Intergovernmental Council for the International Hydrological Programme (IHP) of UNESCO sponsored the preparation of an international handbook on comparative hydrology, emphasizing an ecological approach to land and water resources in various hydrological regions of the world.

The 19 chapters of the IHP handbook were written by invited experts. J. Marsalek, Rivers Research Branch, coauthored the chapter entitled "Human Interventions in the Terrestrial Water Cycle". In their introduction, the authors recognized three phases of water resources development: an initial phase with abundant water resources far exceeding the demands so that natural conditions generally prevail; a second phase when the construction of large systems is required to satisfy increasing demand and in which development of water resources proceeds without integration; and a third phase of integrated multipurpose utilization of water resources. During all three phases, interventions in the terrestrial water cycle take place. Such interventions occur in rural areas as a result of agricultural and silvicultural activities, and in urban areas as a consequence of changes in the catchment cover and intensified demands. Many adverse impacts can be partially or fully remedied by proper planning of water resource development, with emphasis on conservation and attainment of sustainable development.

By wide dissemination of this handbook, UNESCO hopes to increase awareness of the differences in regional hydrology, improve understanding of the impacts of human interventions on the water cycle, and draw attention to remedial measures for mitigation of such impacts.

Reference: Kovacz, G., F.C. Zuidema and J. Marsalek. 1989. Human interventions in the terrestrial water cycle. *In: Comparative Hydrology*, Chapman, T. and M. Falkenmark (Eds.), Chapter 5, pp. 105-130. UNESCO Press, Paris.

Transport of Chlorinated Contaminants in the St. Clair and Detroit Rivers

The total contaminant load transported by a river consists of dissolved contaminants carried by the water as well as contaminants in particulate form carried by the suspended sediments and sediments moving along the river bed. Knowledge of the relative importance of the different transport processes is necessary to understand pollutant pathways and to devise pollution control strategies.

Water flow, sediment transport and concentrations of hexachlorobenzene, octachlorostyrene and polychlorinated biphenyls were measured in three transects in the St. Clair River and two transects in the Detroit River. Transport of chlorinated contaminants in the two rivers were then calculated. It was shown that suspended sediments can often transport the largest amount of contaminants. The amount transported in the soluble phase was, however, of the same order of magnitude as that in the particulate phase. The bed sediments played a negligible role in the transport of contaminants. These results are relevant to pollution control programs for the Upper Great Lakes Connecting Channels.

Reference: Lau, Y.L., B.G. Oliver and B.G. Krishnappan. 1989. Transport of some chlorinated contaminants by the water, suspended sediments and bed sediments in the St. Clair and Detroit rivers. *Environmental Toxicology and Chemistry* (in press).

Certified Reference Materials Brochure

Certified Reference Materials (CRMs) and Reference Materials (RMs) are important tools in assessing the quality of data in environmental research and monitoring. CRMs are stable, homogeneous and well characterized reference materials having very similar matrices to field materials. This minimizes matrix effects between reference and test samples during analysis. RMs are similar to CRMs except that they are less rigorously characterized and are the forerunners of CRMs. Staff of the Quality Assurance Project, Research and Applications Branch, have developed a series of RMs for water analysis, and CRMs for sediment analysis, including several of the world's first lake sediment CRMs. An active program to market these products has been initiated with the production of a bilingual brochure describing the RMs and CRMs developed at NWRI.

Toxic Dye/Particle Interactions in the Yamaska River, Quebec

The adsorption of contaminants onto suspended particles is a key process in controlling contaminant transport in rivers. To better understand and model these adsorption processes, a study was initiated in the ecotoxicology laboratory of NWRI using water from the heavily polluted Yamaska River, Quebec. The Yamaska is contaminated by pesticides from agricultural runoff and by domestic and industrial effluents, mainly textile dyes from local industries.

The distribution of particle-size and the bacterial content associated with each size fraction of suspended sediment was evaluated, and the rates of removal of dyes from the water for each size fraction calculated. The 20-40 micron particle-size fraction, which was the predominant component in the water, exhibited the highest efficiency for binding contaminant dyes. This fraction, rich in organic matter and associated bacteria, probably plays a key role in the transport of contaminant dyes in the Yamaska and similar rivers.

Reference: Rao, S.S., J.H. Weng and B.G. Krishnappan. 1988. Particle associated contaminant transport in the Yamaska River. NWRI Contribution No. 88-104.

Waves and Wave Forecasting

The measurement and analysis of wind-generated surface waves has advanced significantly in the last decade. C.T. Bishop and Dr. M.A. Donelan, Research and Applications Branch, have co-authored a chapter in a volume of a recently published series of civil engineering handbooks. Wind-generated waves and related topics are discussed. Material not available in current text books is included, such as the results of NWRI research into the prediction of mean wave directions on enclosed water bodies. The chapter presents linear wave theory, reviews basic wave processes, summarizes techniques for the measurement of waves and wave direction, explains wave statistics and methods of analysis, and describes simple methods of wave prediction. The text is written for use by civil engineers without an extensive background in hydraulics or coastal engineering.

Reference: Bishop, C.T. and M.A. Donelan. 1988. Waves and wave forecasting. In: *Civil Engineering Practice*, P.N. Chermisinoff, N.P. Chermisinoff and S.L. Cheng (Eds.), Technomic Publishing Co., Inc., Lancaster, Pa, U.S.A., Vol. 3, pp. 653-695.

Historic Variations in Great Lakes Water Levels

According to established geological interpretation, the configurations, outlets and water level variations of lakes Erie, Michigan and Huron have been essentially unchanged for the last 2500 years. However, recent high water levels in the Great Lakes have prompted renewed support for an alternative hypothesis of episodic variations in the level of these lakes related to climate change. This interpretation suggests episodic changes, lasting 200 to 300 years, in the levels of Lake Michigan-Huron of up to 2.5 m above the long-term mean lake level. Such a hypothesis, if true, would necessitate major changes in the planning and management of the Great Lakes. At the request of Public Works Canada, C.T. Bishop of the Hydraulics Laboratory reviewed water level variations in lakes Erie, Michigan and Huron. Historical and

archaeological evidence of European settlements on the Great Lakes was researched and water level computer simulations by the U.S. Great Lakes Environmental Research Laboratory were examined. The results show that mean annual water level excursions of 2 m or more from the long-term mean lake levels are extremely unlikely. In fact, over at least the last 400 years, climate-related variations in maximum mean annual water levels have probably not exceeded those measured on lakes Erie, Michigan and Huron since 1819. These results contradict the hypothesis of episodic climate-related changes in water levels.

Reference: Bishop, C.T. 1988. Historical variation of water levels in lakes Erie and Michigan-Huron. NWRI Contribution No. 88-72.

New Analytical Methods

New and improved analytical methods are continually being developed by the Analytical Chemistry Project, Research and Applications Branch. These methods are in response to specific needs for water pollution research and monitoring programs.

The acid neutralizing capacity of water is an important parameter for studies of aquatic ecosystems, particularly the impacts of acid rain. A recent NWRI contribution describes the determination of the acid neutralizing capacity of water and discusses several related conceptual and terminological problems. The paper describes an automated, conductometric, acid-base titration method developed in cooperation with NWRI's Research Support Division and the National Water Quality Laboratory (NWQL). Perform-

ance of the system was compared to the conventional potentiometric titration method used by the NWQL. Conductometric titration is simple, sensitive and accurate, meeting all the requirements of the NWQL while speeding up the analysis by a factor of five.

In order to monitor the discharge of chlorinated phenolics into lakes and rivers by the pulp and paper industry, a simple and comprehensive analytical scheme for the determination of 31 chlorinated phenolics in pulp and paper mill effluents has been developed. This method is the result of a joint project between NWRI's Research and Applications Branch and Environmental Protection's Wastewater Technology Centre. The method is based on *in situ* acetylation followed by capillary column gas chromatography and electron-capture detection of the acetyl derivatives. The procedure is extended to

monochlorinated phenolics using a mass selective detector in the selected ion monitoring mode. For 50 mL effluent samples, the detection limit is 0.5 µg/L for all compounds, except the monochlorinated compounds, which have a detection limit of 1.0 µg/L.

References

Sekerka, I., J.S. Ford, J.F. Lechner and Y.M. Sheikh. 1988. Determination of acid neutralizing capacity of water and related problems. NWRI Contribution No. 88-103.

Lee, H.B., R.L. Hong-You and P.J.A. Fowle. 1988. Chemical derivatization analysis of phenols. VI. Determination of chlorinated phenolics in pulp and paper effluents. NWRI Contribution No. 88-110.

Workshop on Contaminated Sediments

NWRI (Lakes Research Branch) and the Great Lakes Regional Office of the International Joint Commission (IJC) co-organized a symposium at the Canada Centre for Inland Waters to discuss recent progress on remediation techniques for contaminated sediments and new experimental treatment processes. The four-day meeting brought together over 50 scientists, engineers and water quality managers from Canada, the USA, the Netherlands and the Federal Republic of Germany. Case studies of remediation projects from Alberta, New York, Massachusetts, the FRG and the Netherlands were used to focus attention on practical problems and to identify research and development needs. Opportunities for several demonstration projects in selected Areas of Concern in the Great Lakes Basin were also discussed. The workshop proceedings will be published by the IJC this year.



Conducting experiments in the Clean and Hazardous Chemical Laboratory of NWRI's Research and Applications Branch.

STAFF NEWS

New Appointments

The Institute is pleased to announce the appointments of two research scientists. **Dr. Micheline Hanna** has joined Lakes Research Branch. Her research studies will focus on benthic habitat/contaminant interactions. She recently completed two years of postdoctoral research at McGill University following graduation from the Université Paul Sabatier, in Toulouse, France.

Dr. B.K. Afghan has joined the staff of the Research and Applications Branch. His

research will involve chemical methods development as a member of the Analytical Chemistry Project. Dr. Afghan returns to research after a number of years as Chief of the National Water Quality Laboratory, Inland Waters Directorate, located at CCIW.

Awards, Promotions

Dr. Jan Barica, Senior Limnologist, Lakes Research Branch, has earned a Doctor of Science degree from Charles University in Prague, Czechoslovakia. The prestigious degree recognizes his many

important contributions to limnology, in particular his pioneering research on the hyper-eutrophic lakes of Western Canada. Dr. Barica has also been promoted to the highest level in the federal research classification (Research Scientist-4).

Drs. D.S. Jeffries and W.M.J. Strachan have been promoted recently to the third level of the Research Scientist category for their leadership and achievement in their respective disciplines.

PROJECT FOCUS

NUTRIENT-CONTAMINANT INTERACTIONS PROJECT

Eutrophication and contamination of lakes have traditionally been considered independently of each other by scientists and water managers. Contaminant research has largely focused on the environmental pathways and effects of specific chemicals, whereas eutrophication research has focused on the relationship between nutrient inputs and biological productivity. Although the management of both issues is largely based on the setting of "objectives", nutrient objectives seldom consider the presence of persistent contaminants while contaminant objectives rarely, if ever, consider the trophic state of the system.

The research program of the Nutrient-Contaminant Interactions Project (Lakes Research Branch), is based on the premise that contaminant dynamics and effects in aquatic systems are directly influenced by the trophic state of the system and, therefore, that the eutrophication and contaminants issues cannot be considered separately. The project is attempting to elucidate the mechanisms of interaction between nutrients and contaminants in lakes. Although the knowledge gained will have general application, the major thrust of the project is directed towards the Laurentian Great lakes.

The Great Lakes themselves are too large and contain too many different contaminant sources to allow the systematic investigation of contaminant processes. Therefore, the Model Lakes Ecosystem Study (MODLES) was begun. It involves a series of headwater lakes centred around a field site near Bancroft, Ontario. The study area lies in a region of transition between igneous and sedimentary bedrock where lakes with differing productivity are available for study. Most of these lakes have a single source of contaminants: the atmosphere. The multidisciplinary research program is examining the general hypothesis that nutrients interact with contaminants by influencing four processes: bioaccumulation (and subsequent effects), degradation, sedimentation, and transport. Thus, the objective of the project is to identify the key variables that can be used to predict contaminant bioaccumulation, degradation and sedi-

mentation in lakes and to apply these findings to the Great Lakes.

Contaminant bioaccumulation and effects

In our initial studies, zooplankton from more than 30 MODLES lakes were analyzed for contaminants. A strong inverse relationship between springtime total phosphorus concentrations in the lake water and the concentration of individual contaminants in the zooplankton was discovered. Thus, the premise that trophic status and contaminant dynamics are coupled appears to be correct. The next stage of the project will examine the processes by which trophic status may control contaminant pathways. The most obvious route is by controlling the total mass of biota into which contaminants partition. For some contaminants, strong inverse correlations were observed between the abundance of zooplankton and the concentrations of contaminants they contain. Thus, factors determining zooplankton abundance, such as algal productivity and community structure ("bottom-up" control), fish predation ("top-down" control) and mean depth could be important in predicting bioconcentration. Several less obvious processes by which trophic state can influence contaminants are also being investigated. For example, in very unproductive systems, some phytoplankton produce colloidal polymers. These colloids may enhance bioaccumulation of organic contaminants by algae.

Dissolved organic carbon in lakes may exert a strong influence on contaminant bioavailability, as is the case in terrestrial soils. In order to investigate this factor, methods of isolating natural dissolved organics without chemically altering them have been developed. Using these sensitive methods, samples of dissolved carbon, characteristic of different lake types, are being tested for their effects on contaminant bioaccumulation and partitioning.

Contaminant degradation

Several different aspects of contaminant degradation are under study in the project. We hypothesize that if heterotrophic

bacteria are able to metabolise contaminants, they will do so faster in eutrophic systems. To investigate the influence of nutrient and organic substrates on biodegradation rates, microcosms have been constructed to permit experiments under relatively controlled and reproducible conditions. Other studies are providing increasing evidence that reductive processes are important in contaminant degradation. One of the most important of these is reductive dechlorination (i.e., the replacement of an organically bound chlorine atom by a hydrogen atom). Such reactions are being studied in the laboratory with model reactants and with sediments from MODLES lakes. The ultimate aim is to compare contaminant reactivity in the laboratory with that of the environment. Finally, another study is attempting to identify the dominant yeasts and molds in selected MODLES lakes and to define their role in contaminant degradation.

The trophic state of a water body may also influence the non-biological degradation of contaminants. For example, many compounds for which photolytic breakdown is not normally important exhibit enhanced photolysis rates when natural dissolved organic carbon or algae are present. These reactions appear to proceed via reactive intermediates, such as singlet oxygen, superoxide and hydrogen peroxide, which are produced in natural waters by sunlight. The factors controlling formation of these reactive species in lakes, as well as their subsequent reactions with contaminants, are being studied.

Contaminant sedimentation and transport

The final disposition of some persistent contaminants in lakes is linked with the physical processes of sedimentation, resuspension and sediment transport. Interactions between these physical processes and lake productivity may be important in influencing the distribution of contaminants in lakes and lake organisms. For example, increased nutrient loading may increase the rate of sedimentation of persistent contaminants which could increase contaminant concentrations in benthic organisms and the fish that feed

on them. A major deficiency in measuring these fluxes has been the lack of reliable methods for integrating sediment fluxes in turbulent waters. For this reason, work was begun on the development of a low cost sediment trap capable of functioning under these conditions. A trap has been designed and is being evaluated to determine the influence of currents on catch efficiency. Field calibration of this and other trap designs is also under way.

Project Chief: J.H. Carey

Study Leaders: R.M. Baxter,
F.M. Boyce, B.K. Burnison,
F. Chiocchio, K. Kwasniewska,
D.R.S. Lean, G.G. Leppard.

Project Team: K. Edmondson, J.H. Hart,
D.J. Nuttley

Recent publications

Carey, J.H., D.R.S. Lean, W.D. Taylor and D.J. McQueen. 1989. The influence of lake trophic status on concentrations of atmospherically transported organochlorine contaminants in lake zooplankton. NWRI Contribution No. 89-28.

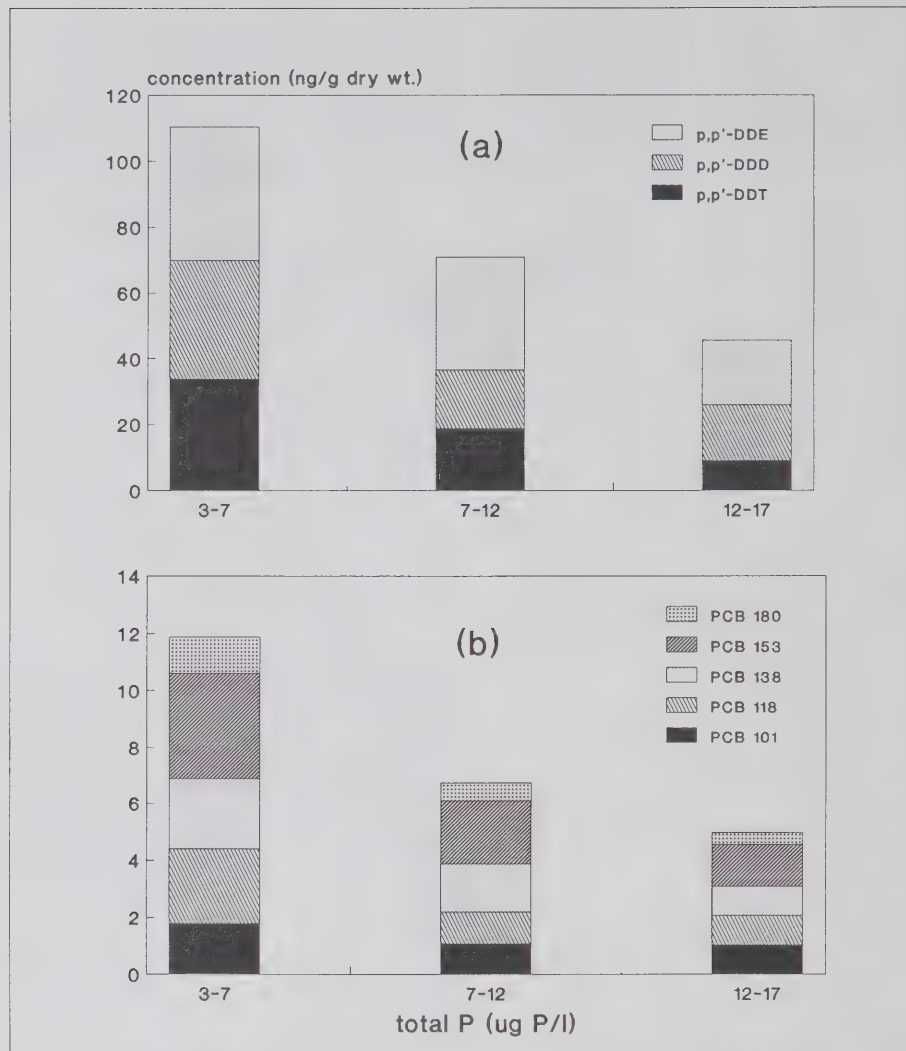
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Baxter, R.M. 1989. Reductive dehalogenation of environmental contaminants: A critical review. NWRI Contribution No. 89-18.

Lean, D.R.S., H.J. Fricker, M.N. Charlton, R.L. Cuhel and F.R. Pick. 1987. The Lake Ontario life support system. Can. J. Fish. Aquat. Sci. 44: 2230-2240.

Leppard, G., J. Buffle, R.R. deVitre and D. Perret. 1988. The ultrastructure and physical characteristics of a distinctive colloidal iron particulate isolated from a small eutrophic lake. Arch. Hydrobiol. 113: 405-424.

Royer, L., F. Chiocchio and F.M. Boyce. 1987. Tracking short-term physical and biological changes in the Central Basin of Lake Erie. J. Great Lakes Res. 12: 587-606.



Average concentrations of (a) DDE, DDD and DDT, and (b) five PCB congeners in zooplankton for lakes grouped by spring total phosphorus values.

RIVER MODELLING PROJECT

Successful river basin management and development in environmentally sustainable ways require a capability to model, predict and optimize complex interactions between natural and anthropogenic factors.

For example, water resources management requires predictive models of water quality and sediment transport, of channel change caused by river structures, and of flooding caused by runoff and ice jams. Habitat management and toxic chemical mitigation require models of contaminant loadings, riverine transport, and chemical fate and effects. Models are important not only for the understanding of complex river ecosystems, but also for predicting the temporal and spatial potential for aquatic impacts. An appropriate choice of models permits managers to select the optimum choices for resource management.

Although models of various riverine processes are continuously being updated and new ones developed, there are many gaps in current knowledge. Only a few simple models have been proven reliable as general tools for river management; these tend to deal with simple parameters, such as oxygen and temperature, or with effluent diffusion.

The River Modelling Project combines the study of physical, biological and biochemical processes with deterministic, quantitative synthesis and predictive techniques. Emphasis is on practical management issues in Canada's rivers and basins.

Inter-disciplinary research and collaboration with other projects at NWRI enables study of more complex problems. There is also extensive interaction with scientists developing expert systems for acid rain modelling.

Non-point sources of pollution

Despite recent improvements in the control of polluted municipal and industrial effluents, known as point sources, water quality goals often remain unattainable without characterization and control of non-point source pollution, such as from agricultural and urban runoff. Ongoing studies have resulted in the development of loading functions for different contaminants transported by urban runoff and for various types of urban developments. Agricultural runoff work has only begun recently, with a focus on nutrients and pesticides. A small research catchment in the Upper Thames watershed is being instrumented to provide field data needed in development of agricultural runoff models.

Participation in the inter-branch study of Hamilton Harbour, a seriously polluted

water body, has resulted in quantification of the combined sewer outflows into the harbour.

Fine river sediments

The strong adsorptive capacity of fine particles and their abundance in suspension make them major "carriers" of toxic substances in river waters. Despite the past successes of coarse-sediment research, little is known about the hydrodynamic behaviour of fine particles, because they are strongly influenced by their tendency to flocculate and form "cohesive" bonds. A major study has been initiated to address this knowledge gap. The program includes mathematical modelling of the flocculation process and its effects on erosion and deposition rates, laboratory experiments in rotating flumes to provide the fundamental knowledge and data needed for modelling, and field measurements to identify natural conditions and ranges of parameters. Instrumentation for measurement of the size distribution of primary particles and of flocs is being acquired and adapted for laboratory and *in situ* field uses. Such measurements have been made possible by recent advances in laser-optical techniques.

A parallel study on the particulate transport of organic contaminants has also begun. Much of the modelling done to date relies on laboratory-derived parameters of partitioning between the solid and liquid phases. The study is intended to verify or modify this approach using extensive field data in representative streams.

Ice regimes

The formation and breakup of ice in Canadian rivers has many repercussions on flood-plain management, northern development and hydro power production (e.g., clogging of reservoirs by frazil ice, head losses due to anchor ice, flooding due to ice jams). Because of the complexity of ice phenomena and lack of adequate data, river ice modelling is still in its infancy.

With partial support from the hydro power industry, a laboratory study was recently initiated to investigate the transport, flocculation and evolution of frazil ice, the tiny ice crystals that appear in rivers as soon as the water temperature drops just below the freezing point. The study will, at a later stage, include the related phenomenon of anchor ice that can accumulate on stream beds.

Research into ice breakup, ice jams and related flooding includes field and laboratory work. In cooperation with the New

Brunswick Department of Municipal Affairs and Environment, ice jam processes in the Restigouche River, New Brunswick, are being documented. The Restigouche is a large northern stream and, in a hydroclimatic sense, represents the opposite to the small streams of southwestern Ontario that have already been studied under our ice program.

A synthetic material (SYG-ICE) has been developed for laboratory study of ice breakup and jamming. SYG-ICE has the correct structural properties needed to simulate an ice cover at laboratory scale and room temperature.

NWRI is also a co-sponsor, participant and scientific authority in the development of a comprehensive river ice model for Canadian water resource management applications. Initiated in 1988, this multi-agency, Canadian-led effort is scheduled to be completed in 1991. This project will cost an estimated \$2 million.

Optical monitoring systems

An important component of research on aquatic processes is the capability to monitor water quality remotely and on a continuous basis. Past work on optical methods has produced successful techniques for measuring basic water quality parameters in lakes. For example, chlorophyll and dissolved organic carbon can be related to subsurface irradiance reflectance. This work uses mathematical algorithms of spectral characteristics to obtain correlations between water quality parameters and spectral information obtained from satellite, aircraft or *in situ* optical instruments.

Our optical monitoring research is now being extended to include real-time, river applications. The MOMS (multi-spectral optical monitoring system), developed earlier at NWRI, is being adapted to monitor river concentrations of suspended sediment on a continuous basis during both daylight and night-time hours. This would greatly improve present capabilities that rely on site visits and manual sampling.

Project Chief: S. Beltaos

Study Leaders: B.G. Brownlee, R.P. Bukata, B.G. Krishnappan, Y.L. Lau, J. Marsalek, G. Tsang.

Project Team: J.E. Bruton, J. H. Jerome, G.A. MacInnis, H. Ng.

Recent publications

Beltaos, S. 1988. Configuration and properties of a breakup jam. *Can. J. of Civ. Eng.* 15: 685-697.

Bruton, J.E., J.H. Jerome and R.P. Bukata. 1988. Satellite observations of sediment transport patterns in the Lac Saint-Pierre region of the St. Lawrence River. NWRI Contribution No. 88-87.

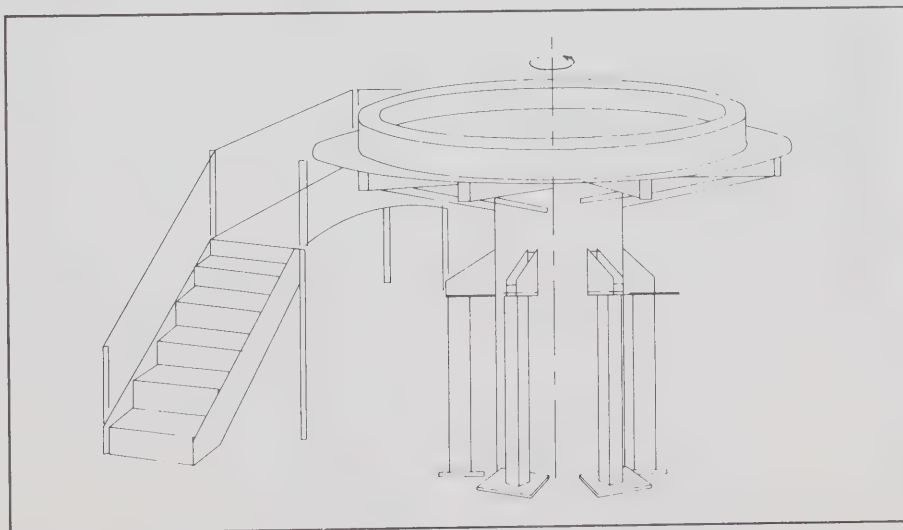
El-Shaarawi, A.H., A. Maul and B.G. Brownlee. 1988. Modelling to dissolved oxygen change in streams using non-linear regression analysis. *Environment Canada IWD Scientific Series No. 163.*

Krishnappan, B.G. 1988. Modelling of settling and flocculation of fine-grained sediments. *J. Hydraul. Eng., American Society of Civil Engineers* (submitted).

Lau, Y.L. 1988. Modelling of single grain and floc settling. NWRI Contribution No. 88-100.

Marsalek, J. and H. Schroeter. 1989. Annual loadings of toxic contaminants in urban runoff from the Canadian Great Lakes Basin. *Water Poll. Res. J. Canada* (in press).

Tsang, G. 1988. Development of mathematical modelling for prediction of river cooling and frazil and anchor ice formation. In: *Proc. 5th NRC Workshop on Hydraulics of River Ice*, Winnipeg, Manitoba (in press).



Rotating annular flume for fine sediment transport research (under construction). A counter-rotating annular ring, not shown, will rest on the water surface to generate appropriate shear and to minimize secondary circulation. Outside diameter = 5 m; flume width = 30 cm; flume height = 30 cm.

Sustainable Development Symposium

On Friday, February 17, a one-day Sustainable Development Symposium was held by NWRI. Attended by over 300 research scientists, engineers, technicians and other research support personnel, the symposium sought to explain the critical issues surrounding the United Nations "Brundtland Report" and to review the goals and implications of sustainable development. It also marked the beginning of a process to re-evaluate the long term strategic direction of the Institute in support of sustainable development goals in Canada and abroad.

The morning session, chaired by Dr. Ted Manning, Chief, Conservation Strategies, Canadian Wildlife Service, featured David Runnalls, Associate Director, Sus-

tainable Development Division of the Institute for Research on Public Policy. Mr. Runnalls discussed sustainable development in the global context. He was followed by Colin Isaacs, Executive Director of Pollution Probe, who presented an environmental perspective of sustainable development. The industrial viewpoint was given by Adam Zimmerman, Chairman and Chief Executive Officer of Noranda Forest Inc. The final speaker in the morning session was Anthony Cassils, Vice-President, CFG Heward Investment Management Ltd., who covered the economic aspects of sustainable development.

The afternoon session was devoted to the federal government perspective, both

national and international, chaired by Bev Burns, Director General, Conservation and Protection, Western and Northern Region. Speakers included Dr. Leslie Whitby, Director, Sustainable Development Branch, Canadian Wildlife Service; Dr. Andrew Hamilton, International Joint Commission; and Dr. Fred Roots, Science Advisor to the Deputy Minister, Environment Canada, who summarized the day's presentations. To conclude the program the speakers formed a panel to answer questions from the audience.

The symposium was informative and thought-provoking, providing a common base of understanding for future analysis and action. Consideration is being given to producing published proceedings of the symposium.

COMING EVENT

June 12-13, 1989: *Workshop on Pesticide Contamination of Canadian Ground Waters*. The workshop, to be held in Saskatoon, is organized in conjunction with the National Hydrology Research Institute/Canadian Water Resources Association (NHRI/CWRA) Symposium on Ground Water Contamination. The purpose of the workshop is to review present research and regulatory programs defining the occurrence of pesticides in ground water and to discuss future directions for research and regulation with respect to the ground water resource. For more information, contact the organizers, G. Grove, NHRI (Saskatoon), at (306)975-5741, or R.E. Jackson, NWRI, at (416)336-4587.

About NWRI

Environment Canada's National Water Research Institute (NWRI) conducts a national program of original research and development in the aquatic sciences, in partnership with the international freshwater science community. The twin goals of the Institute are to advance scientific understanding of national and international water issues important to Canada and to develop knowledge and authoritative expertise on these issues that can be used by Environment Canada to influence decisions affecting the wise management of Canada's water resources.

Research at NWRI is conducted within multidisciplinary projects, each focusing on a priority issue. Projects are grouped within three branches, the Lakes Research Branch, the Rivers Research Branch, and the Research and Applications Branch. Current long-term research priorities include: toxic chemicals in the Great Lakes and the St. Lawrence River; exchange of toxic contaminants between air, water, sediments, and biota; groundwater contamination; pesticide contamination in rivers; acid rain; lake rehabilitation; and aquatic monitoring, ecotoxicology, and risk prediction methodologies.

NWRI Digest

The NWRI Digest is the quarterly public newsletter of the National Water Research Institute, Conservation and Protection, Environment Canada. Suggestions, comments and further enquiries concerning newsletter items are welcomed. Please write to the Editor, NWRI Digest, National Water Research Institute, P.O. Box 5050, Burlington, Ontario, Canada L7R 4A6.

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SUSTAINABLE DEVELOPMENT AND WATER RESEARCH

The Symposium on Sustainable Development convened by NWRI in February 1989 represents an important milestone in the Institute's life. It is now clear to most environmental scientists that we must support and act on the recommendations of the United Nations' World Commission on Environment and Development. The Brundtland Report, as it is called, provides the most positive, pragmatic and action-oriented environmental philosophy yet articulated to regain global environmental security.

INSIDE

- Application of the RAISON Expert System in Malaysia
- Biomonitoring of Organic Contaminants in the St. Lawrence River
- Hamilton Harbour Flushing Processes
- Trophic State Indicator for the Great Lakes
- Automated Method for Boron in Water
- New Chloronitrobenzene Method
- Analysis of Nitrogen-Containing PAHs in Sediments
- Analysis of Trace Organics in Environmental Samples
- Technology Transfer Mission to Bangladesh and Pakistan
- Research on Fine Sediment in Rivers
- Patent on Frazil Ice Instrument
- Agriculture Canada's Regulation on Tributyltin
- Groundwater Contamination Project
- Analytical Chemistry Project

Equally clear is the special position of water in sustainable development. Long-term supplies and good quality water are a critical prerequisite for sustainable development. The water sector is therefore a key factor in future planning, and water research contributes directly to the rational conservation and management of aquatic resources.

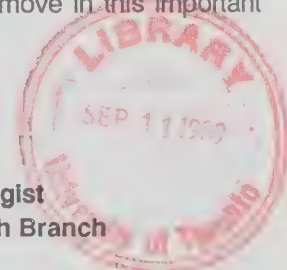
What changes in emphasis or direction at NWRI could strengthen our contribution to this global effort? In our view, the Institute's current research programs on environmental protection and remediation (e.g., toxic contaminants, acid/toxic rain and climate change) are important and must continue. Nevertheless, sustainable development should serve increasingly as the critical framework for future program planning. New interdisciplinary studies concerned with ecosystem sustainability will need to be initiated. Better understanding is needed of aquatic ecosystem integrity, stability and "carrying capacity", while new tools must be developed to forecast and predict the aquatic impacts of present and future development. In particular, we will need to forge new partnerships with economists and social scientists, a difficult but critical departure from our traditional way of doing business.

The Brundtland Report emphasized the global character of sustainable development. Whatever is done in one country or continent affects all others. Simi-

larly, the science and technology that will be needed to bring about sustainable development must be created internationally and shared around the world. To this end, we believe that NWRI, with its long-standing focus on international issues, has an important role to play. Two decades of research experience from the Great Lakes Basin, for instance, is a valuable asset we can offer to the international scientific community. The basin and some of its Areas of Concern can serve as case studies of international remediation, pollution prevention and inter-jurisdictional management. Greater international involvement will permit efficient use of pooled resources to mutual benefit and provide new knowledge of the ecological limits to sustainable development.

The Brundtland Report, when viewed from a scientific perspective, clearly indicates the need for a new era in environmental research, one which focuses on understanding and predicting ecological sustainability. We believe there is the commitment and expertise within NWRI to move in this important direction.

J. Barica
Senior Limnologist
Lakes Research Branch
and
R.J. Daley
Chief, Science Liaison Division



RESEARCH NEWS

Application of the RAISON Expert System in Malaysia

Dr. D.C.L. Lam, Rivers Research Branch, was invited by the International Development Research Centre (IDRC), Ottawa, to adapt and implement the RAISON (regional analysis by intelligent systems on a micro-computer) expert system for a water quality data management study in Malaysia, as part of a technology transfer program of Canadian scientific know-how to developing countries. Dr. Lam and J. Storey (University

of Guelph) conducted a work session in Kuala Lumpur in January 1989. Water quality and sanitary survey data from over 500 sampling stations in Malaysia are now stored and displayed in the RAISON/MALAYSIA system. Dr. Lam also presented seminars on the RAISON system at the Department of Environment and the Environmental and Research Association of Malay-

sia. The RAISON expert system was developed at NWRI and has been used to predict acid rain effects based on several management scenarios. It is being used extensively in preparation for the 1990 National Assessment required by the federal-provincial Research and Monitoring Coordination Committee of the Long Range Transport of Atmospheric Pollutants (LRTAP) program.

Biomonitoring of Organic Contaminants in the St. Lawrence River

J.L. Metcalfe, Rivers Research Branch, and M.N. Charlton, Lakes Research Branch, undertook a study to evaluate native unionid mussels as biomonitors for organic contaminants in the St. Lawrence River. Unionid mussels are large, abundant, sedentary, non-selective in terms of habitat, and easily standardized for sources of biological variability, hence, they are ideal candidates for biomonitoring.

Native freshwater mussels (*Elliptio planata* and *Lampsilis radiata radiata*) provided information on the origin, bioavailability and persistence of organic contaminants in the St. Lawrence River ecosystem. Individual mussels were analyzed for 7 organochlorine pesticides, 11 chlorobenzenes, octachlorostyrene, and 63 PCB congeners. Bioconcentration patterns in mussel tissues implicated Lake Ontario as the source of mirex and DDT derivatives, and the Grass River as the major source of PCBs to the system. Numbers of PCB congeners in mussels increased from 21-27 in the upper river to 56-59 in the Cornwall/Massena industrial area. An average of 43 congeners persisted as far downstream as Lake Saint-Pierre. Concentrations of most contaminants in mussels from

the Ottawa River were 50-75% lower than the lowest values reported for the St. Lawrence River. Spatial distribution patterns for contaminants in mussel tissues generally reflected the known distribution of these compounds in bottom sediments and clearly identified the major sources of several important contaminants, including DDT derivatives, mirex and PCBs. Congener-specific PCB analysis provided information on the persistence of various PCB compounds in mussels living downstream of the point source.

Biomonitoring with mussels has several potential applications. It may be used to complement or supplement traditional ambient water and sediment monitoring programs, primarily to provide information on bioavailability. It can also be used to define the impact zone of point source pollution and to serve as a feedback mechanism for determining the effectiveness of pollution control measures as they are implemented.

Reference: Metcalfe, J.L. and M.N. Charlton. 1989. Freshwater mussels as biomonitors for organic industrial contaminants and pesticides in the St. Lawrence River. NWRI Contribution No. 89-60.

Hamilton Harbour Flushing Processes

The effects of the two-way exchange of water between western Lake Ontario and Hamilton Harbour on the harbour's water quality have been investigated by NWRI and the Ontario Ministry of the Environment. The joint study demonstrated the beneficial effects to the harbour of the episodic, but substantial, inflow of relatively clean water from Lake Ontario. During the period of thermal water stratification, water inflow from the lake increased the dissolved oxygen content of the hypolimnion in the harbour. With the concurrent outflow from the harbour, however, contaminants associated with suspended sediments are transferred to Lake Ontario. The contaminant transfer is greater than would have been predicted for a similar size water body without a complex and dynamic outlet like the ship canal. This new knowledge on water mass discharge from the harbour may affect the remedial options being formulated for the Hamilton Harbour Remedial Action Plan by both the federal and provincial governments.

Reference: Barica, J., D. Poulton, B. Kohli and M.N. Charlton. 1988. Water exchange between Lake Ontario and Hamilton Harbour: water quality implications. Water Poll. Res. J. Canada 23: 13-26.

Trophic State Indicator for the Great Lakes

In pre-settlement times, some areas of the Great Lakes could have been classified as mesotrophic (e.g., Green Bay, Saginaw Bay, and the western basin of Lake Erie). These areas are now eutrophic, but several water quality parameters indicate they are not as eutrophic as before. An integrative indicator is therefore required to indicate the re-establishment of mesotrophic conditions, which is the targeted objective for these areas. Dr. T. Reynoldson, Lakes Research Branch, and two scientists from the U.S. Fish and Wildlife Service have examined the utility of using densities of mayfly larvae (*Hexagenia limbata*) in the sediments as an indicator of the lake trophic state. They concluded that when the mayfly densities reach 200 individuals per square metre, the aquatic ecosystem would be considered mesotrophic with concurrent improvements in fish production and water clarity.

Reference: Reynoldson, T.B., P.W. Schloesser and B.A. Manny. 1989. Development of a benthic invertebrate objective for mesotrophic Great Lakes. NWRI Contribution No. 89-02.

Analysis of Nitrogen-Containing PAHs in Sediments

Nitrogen-containing polycyclic aromatic hydrocarbons are formed in combustion processes and are reportedly more toxic than polycyclic aromatic hydrocarbons (PAHs). At the request of the Great Lakes Toxic Contaminants Committee, a relatively fast and simple method for the detection and quantitation of azaarenes (nitrogen-containing PAHs) in sediment samples has been developed and reported by Dr. F. Onuska and K. Terry, Research and Applications Branch. The method reports detection limits of 1 to 10 µg/kg and can be integrated with procedures for PAHs. Analysis of the azaarenes is achieved using open tubular column gas chromatography with thermionic detection and mass spectrometry. The method was applied to Hamilton Harbour sediment samples and recoveries of individual azaarenes evaluated.

Reference: Onuska, F.I. and K.A. Terry. 1988. Identification and quantitative analysis of nitrogen-containing polycyclic aromatic hydrocarbons in sediments. NWRI Contribution No. 88-79.

New Chloronitrobenzene Method

Chloronitrobenzenes have been reported in fish samples in the U.S. and Europe, but no validated analytical methods are available for these compounds in water and fish tissue. Dr. H.B. Lee, Research and Applications Branch, and G.D. Kissoon of the Bayfield Institute, Department of Fisheries and Oceans, have developed a method for quantitative analysis of 14 chloronitrobenzenes in water and fish. The compounds are extracted with dichloromethane and cleaned up, using gel permeation and/or adsorption chromatography. Analysis is performed using capillary column gas chromatography with electron-capture detection. Detection limits of 2 ng/L for water samples and 5 ng/g for fish samples are possible. Confirmation is achieved by selected ion monitoring using two characteristic ions. The method, with only minor modifications, can be integrated into other methodologies for organochlorine insecticides.

Reference: Lee, H.B. and G.D. Kissoon. 1989. Determination and confirmation of chloronitrobenzenes in water and fish samples. NWRI Contribution No. 89-81.

Analysis of Trace Organics in Environmental Samples

Drs. B.K. Afghan and A.S.Y. Chau of the Research and Applications Branch edited a recently released book entitled "Analysis of Trace Organics in Aquatic Environment." The publication covers the practical aspects of analytical methodology for trace organics in environmental samples. It reviews the published work on the analysis, occurrence, distribution, fate, effect and environmental impact of specific classes of compounds. Essential background information on the advantages and disadvantages of the various published methods is also discussed. The book contains chapters on volatile halogenated and purgeable organics, polychlorinated biphenyls, toxaphene, phenols, chlorinated dibenzop-dioxins and dibenzo furans, polycyclic

aromatic hydrocarbons, phthalate, esters, organometallic compounds and humic substances.

The work is intended to serve as a general reference for university and college students, as well as a practical reference for environmental chemists and technologists. Each chapter covers practical applications of techniques, and provides state-of-the-art methodologies in current use with special reference to pumping, concentration, cleanup, quantitative and confirmatory analysis.

Reference: Afghan, B.K. and A.S.Y. Chau [eds.]. 1989. Analysis of Trace Organics in Aquatic Environment. CRC Press, Inc., Boca Raton, Florida, 384 p.

Patent on Frazil Ice Instrument

An instrument developed at NWRI for measuring the concentration of frazil ice has just received a Canadian patent. The patent, submitted by Dr. G. Tsang and M. Pedrosa, Rivers Research Branch, contains 15 claims. The instrument, which quantifies the percentage of ice in water, will be particularly useful at power plants for monitoring frazil ice and deciding when to take action to prevent its formation at water intakes. In extreme cases, adhesion of frazil ice and the resultant formation of anchor ice can shut down the power plant. A licence for manufacturing the instrument has been acquired by Artec Canada.

Research on Fine Sediment in Rivers

Suspended sediments often carry with them a large portion of the toxic contaminants which enter rivers and lakes. Hydrodynamic processes governing fine sediments are thus important to understanding the fate and pathways of such contaminants. The Rivers Research Branch (RRB) continues to investigate fine sediment transport and its effects on other riverine processes.

The importance of fine sediments in toxic chemical transport and the basic knowledge requirements for the development of mathematical models of fine sediment transport have been reviewed by Drs. B. G. Krishnappan and E.D. Ongley (RRB). Flocculation was identified as the most important process requiring further research. Flocculation affects the fall velocity of fine-grained sediments which, in turn, affect rates of settling and deposition. At present, these processes cannot be calculated accurately.

As part of NWRI research program on fine sediment transport, Dr. Y.L. Lau, RRB, has now developed a mathematical model of the settling process. The model has been used with data on settling to investigate the rate of flocculation. Results show that flocculation increases as the square of the concentration.

In another study, satellite data from the Landsat 4 and 5 satellites were utilized to illustrate the seasonal patterns of sediment transport and mixing in the Lake Saint-Pierre region of the St. Lawrence River. Landsat data were used to delineate turbidity zones, their seasonal patterns and their relationships with both bottom topography and near-surface temperature. Extended zones of turbidity were identified which were independent and temporally persistent. This information will be useful in planning field strategies to better understand the fate of materials injected into the ecosystem.

References

Bruton, J.E., J.H. Jerome and R.P. Bukata. 1988. Satellite observations of sediment transport patterns in the lac Saint-Pierre region of the St. Lawrence River. NWRI Contribution No. 88-87.

Krishnappan, B.G. and E.D. Ongley. 1988. River sediments and contaminant transport : changing needs in research. NWRI Contribution No. 88-95.

Lau, Y.L. 1988. Modelling of single-grain and floc settling. NWRI Contribution No. 88-100.

Automated Method for Boron in Water

Boron occurs naturally in small amounts ($\mu\text{g/L}$) in most Canadian waters and is also released as an industrial and domestic pollutant. Boron, in the form of borates, is also an important component of the acid/base neutralizing system of natural waters and, hence, reliable boron data are important in the study and management of acid rain. At the request of the National Water Quality Laboratory, a sensitive, automated method for the determination of boron has been developed in the Research and Applications Branch. The method employs flow injection analysis with on-line ion exchange pre-concentration and the colorimetric determination of the azomethine-H boron complex. The detection limit of the method was $1 \mu\text{g/L}$ when ten samples were run per hour ($5 \mu\text{g/L}$ at 20 samples per hour). For concentrations between 1 and $10 \mu\text{g/L}$, the relative standard deviations (RSDs) were 10% or less; for higher concentrations ($10\text{--}200 \mu\text{g/L}$), the RSDs were 5% or less. The method is quantitative, convenient, interference-free and requires no sample pre-treatment.

Reference: Sekerka, I. and J.F. Lechner. 1989. Automated method for the determination of boron in water. NWRI Contribution No. 89-93.

Technology Transfer Mission to Bangladesh and Pakistan

Dr. B.G. Krishnappan, Rivers Research Branch, was one of three members of a Canadian delegation chosen by the Canadian Society for Civil Engineering for a recent technology transfer mission to Bangladesh and Pakistan financed by the Canadian International Development Agency (CIDA). Dr. Krishnappan conducted workshops on

the MOBED model at Dacca in Bangladesh, and Karachi and Lahore in Pakistan. The flood-level predicting capability of the model was emphasized at Dacca, since there is a great need in Bangladesh for flood level forecasts. In Pakistan, discussions centred on prediction of tidal flows and sedimentation in shipping channels and on the

responses of river systems to stresses resulting from irrigation schemes. Lahore has one of the most sophisticated irrigation systems in the world. Strong interest was experienced in the MOBED model. The mission provided an effective opportunity to promote the Canadian technology developed at NWRI in these two developing countries.

STAFF NEWS

New Appointments

Dr. T. Reynoldson of the Lakes Research Branch has been appointed as the Canadian Co-chairman of an International Joint Commission bi-national committee. For the next two years, the committee will be de-

veloping ecosystem objectives for the Great Lakes in support of the revised Great Lakes Water Quality Agreement (GLWQA). The 1987 revision of the GLWQA of 1978 calls for the development of lake ecosystem objec-

tives for each lake which recognizes the characteristics needed to maintain the chemical, physical and biological integrity of the aquatic ecosystem.

Dr. H.H. Vaughan has joined the staff of the Rivers Research Branch where he will work as Science Liaison Officer. Before joining NWRI, Dr. Vaughan was Head, Monitoring and Agreements of Water Quality Branch, Western and Northern Region. He has also worked for the Canadian Wildlife Service and the Nova Scotia Department of the Environment.

Awards

M. Comba, research technologist with the Lakes Research Branch, has received a Departmental Merit Award for his outstanding contribution to the success of field and laboratory studies on the transport, fate and effects of contaminants in the St. Lawrence River.

N. Harper, research technologist with the Lakes Research Branch, has received a Departmental Citation of Excellence for her initiative and perseverance in coordinating the Employee Assistance Program at the Canada Centre for Inland Waters.

PROJECT FOCUS

GROUNDWATER CONTAMINATION PROJECT

Leaching from waste disposal sites and pesticide used in agriculture contribute to groundwater pollution that contaminate wells and also, sometimes, surface waters. In Eastern Canada, groundwater is particularly important, especially in southern Ontario, the St. Lawrence valley and the Maritime provinces, where it is used for municipal, agricultural and industrial needs.

The research program of the Groundwater Contamination Project (Rivers Research Branch) focuses on the migration and fate of toxic contaminants in groundwater using instrumented field sites, laboratory experiments, and mathematical models done in collaboration with the University of New Brunswick.

There are three general objectives to the work: 1) to understand the physical and chemical controls on contaminant migration and fate in sedimentary rock aquifers; 2) to develop and/or apply operational tools for hazardous waste site assessment and restoration of outwash aquifers; 3) to provide expert advice on groundwater pollution matters of federal concern in Eastern Canada.

Hydrogeology of the Niagara frontier

About 164 hazardous waste sites have been identified within five kilometres of the Niagara River on the U.S. side of the Canada-U.S. border. Seepage from these sites poses a grave threat to the quality of both the Niagara River and Lake Ontario. A cooperative study between hydrogeologists from NWRI and the U.S. Geological Survey is under way to understand the regional groundwater flow patterns on both sides of the frontier. During 1988, 150 hydraulic

tests in two boreholes in the fractured bedrock of the Niagara Falls (New York) area were conducted to identify the hydraulic properties of the fractured bedrock and to define the regional groundwater flow pattern in this contaminated area.

Hydrogeological assessment of hazardous waste sites

NWRI scientists are working with engineers from the Wastewater Technology Centre at the Canada Centre for Inland Waters and various consulting firms to appraise groundwater contamination at several hazardous waste sites at which federal funds are being spent to restore aquifers or to assess cleanup options. These sites include the Uniroyal Chemicals plant in Elmira, Ontario; the Ville Mercier dump site, south of Montréal; the coke oven site at the Sydney Steel Works, Nova Scotia; and the Gloucester Landfill site, near Ottawa. The review of these studies revealed that proper hydrogeological and chemical investigation of the site is required prior to selection of appropriate remedial technologies in order to minimize the cleanup costs.

Hydrogeology of fractured rock

A field site at Petro-Canada's Clarkson, Ontario, refinery has been established jointly by the Waterloo Centre for Groundwater Research and NWRI. The site is used to assess the importance of fracture apertures, spacings and orientations on the hydraulic properties of sedimentary rocks. The work is of primary importance in the Great Lakes region because of the intimate relationship between bedrock fractures and the migration of toxic chemicals from hazardous waste sites.

Data were obtained from 13 boreholes on the site. An analytical model and a graphical method were developed for the analysis of the hydraulic tests used to assist in the interpretation of the field data. Two independent fractures were found in the shale bedrock at 9.8 and 10.5 metres depth with mean apertures of 53 and 104 micrometers. Laboratory simulations of these fractures suggest that slight variations in mean aperture width lead to substantial channelling of contaminants in fractured rock, thereby making the task of predicting contaminant transport in fractured rock even more difficult.

Biodegradation of groundwater contaminants

Detailed chemical analysis of groundwaters contaminated with organic solvent residues at the Gloucester Landfill site, near Ottawa, have shown the presence of several freon products. The parent compound is F113, a solvent used in chemical analysis and in microelectronic manufacturing and associated with several very large plumes of contaminated groundwater in the United States. NWRI scientists have discovered that this seemingly stable compound, associated with ozone degradation in the upper atmosphere, is in fact unstable in anoxic groundwater and breaks down by reductive dehalogenation and elimination reactions.

While F113 is quite harmless, there is concern that the degradation products are not, in particular F1113, an analog of the human carcinogen vinyl chloride. Cooperative studies with U.S. workers have shown that these biotransformation reactions are probably the result of free radical formation involving cytochrome P-450 enzyme systems.

Fate of aldicarb in the sandstone aquifer of PEI

Continued monitoring of aldicarb pesticide contamination of the sandstone aquifer of Prince Edward Island has shown that aldicarb is extremely persistent in the acid soils beneath the potato fields on which it is used. Despite its high mobility in soils and the fractured sandstone aquifer, aldicarb has remained at relatively high concentrations in the aquifer for over two years since its last application.

Detailed monitoring over the course of one month demonstrated that 10% of all of NWRI's monitoring wells had aldicarb concentration in excess of the National Health

and Welfare's 9 ppb drinking water guideline, but 50% had nitrate concentrations in excess of the 10 ppm guideline. This suggests that nitrate may pose a more serious groundwater contamination problem in the Maritimes.

Project Chief: R.E. Jackson

Study Leaders: A.S. Crowe, S. Lesage, K.S. Novakowski

Project Team: P.A. Lapcevic, M.W. Priddle

Recent publications

Crowe, A.S., R.E. Jackson, S. Lesage and M.W. Priddle. 1988. Contamination of groundwater

from the Gloucester Landfill at the Ottawa International Airport. *In Proceedings of Environmental Workshop '88. Environmental Issues at Federal Facilities*, Winnipeg, Manitoba, Transport Canada.

Jackson, R.E. and K.J. Inch. 1989. The *in situ* adsorption of Sr 90 in a sand aquifer at the Chalk River Nuclear Laboratories. *J. Contaminant Hydrology* 4(1): 27-50.

Jackson, R.E., S. Lesage and M.W. Priddle. 1989. Sampling and analysis of groundwater quality at hazardous waste sites in Eastern Canada. Symposium on Ground Water Contamination, Saskatoon, Saskatchewan, June 1989 (in press).

Lesage, S. 1989. Solid-phase sample collection for the analysis of aldicarb residues in groundwater. *LC-GC* 7(1): 270-271.

Raven, K.G., K.S. Novakowski and P.A. Lapcevic. 1988. Interpretation of field tracer tests of a single fracture using a transient solute storage model. *Water Resources Research* 24(12): 2019-2032.

ANALYTICAL CHEMISTRY PROJECT

The main objectives of the Analytical Chemistry Project of the Research and Applications Branch are: to develop new and improved analytical methods as well as screening and sampling procedures which are accurate, cost-effective, sensitive and unambiguous for the identification and quantification of contaminants in aquatic ecosystems; to play a lead role in documentation, validation and standardization of analytical methodologies to ensure accuracy and reliability of analytical data; to provide NWRI with sophisticated instrumentation and facilities; and to transfer developed methods and technologies to the national and regional laboratories of Inland Waters Directorate and a wide variety of other "clients".

Operation of sophisticated instrumentation and facilities

A tribrid mass spectrometer has been acquired jointly by NWRI and the National Water Quality Laboratory. This instrument will be used by NWQL for routine analyses of organics and by NWRI for research activities on mass spectrometry. Due to the versatility of the instrument, many advanced mass spectral experiments are available for future research works (e.g., linked scanning of parent and daughter ions, high and low energy collision-induced dissociations, ion molecule reactions by fast atom bombardment, thermal spray and plasma spray LC-MS, etc.).

The Clean and Hazardous Chemicals Laboratory operated by the Project is providing analytical data for highly toxic contaminants at ultra-trace levels. The laboratory offers maximum protection to workers and minimizes cross-contamination of samples. Currently, priority samples are being analyzed for dioxins and furans. Gravity flow chromatography, flash chromatography, and solid phase extraction and cleanup procedures will be investigated to develop faster and improved methods for sample treatment.

Detection of toxic and mutagenic effects at sub-cellular level

The evaluation of pollutants in terms of their toxic, carcinogenic and mutagenic effects is largely confined to the determination of mortality, the occurrence of tumours and of imperfections in offspring. It is appropriate then to look at sub-cellular level to determine what causes death, tumour formation and deformed young. Laboratory techniques are developed to routinely determine and characterize compositional and physiological changes in genetic material and associated protein substances. The techniques will provide the capability to screen, categorize and regulate environmental contaminants with a much greater appreciation for their potentially detrimental effects.



Chemist doing on-site groundwater measurements in a 200-metre borehole at Navy Island in the Niagara River, Ontario.

Development of analytical methods

The liquid chromatography (LC) with multi-detection capability offers a great potential for environmental analysis. A wide range of compounds can be analyzed, ranging from volatile to non-volatile, with molecular weights differing as much as 3-4 orders of magnitude from each other. The high pressure/liquid chromatography multi-detection system will be used for developing improved methods for polynuclear hydrocarbons. The analytical potential of the above system, in conjunction with pre-column and post-column derivatization, will be explored.

Optimization of gas-liquid chromatography, coupled with advanced computer techniques, will be used to systematically group unknown peaks in the chromatograms of environmental samples. Result files from the data-collecting computer will be transferred to powerful PCs that will then enter the results for target compounds into a "spread sheet" format which can be transmitted to the VAX or made available to the client.

Screening techniques are developed for the detection of trace organic contaminants. In previous years, a radioimmunoassay (RIA) for the detection of polychlorinated dibenzo-p-dioxins was developed. In that work problems were experienced with the labelled dioxin derivative (hapten) used in the RIA. An alternative hapten has been synthesized and will be fully evaluated in the RIA using both polyclonal and monoclonal antibodies. The extraction and cleanup method will undergo final validation at low spiking levels. Evaluation of two immunoassay methods for the detection of atrazine and related triazine herbicides in water will also be completed. An improved rapid extraction and cleanup procedure for use with these immunoassays will be developed and validated.

An analytical method for the determination of the resin and fatty acids commonly found in pulp mill effluents is to be developed. Existing methods lack the sensitivity required for many environmental samples. The formation, GC resolution, cleanup and analysis of the pentafluorobenzyl ester derivatives of the resin and fatty acids will be examined. The use of NICI-MS for the confirmation and quantitation of resin and fatty acid in complex effluent extracts will be examined.

Organic acids are relatively less known than inorganic acids, partly due to the fact

that they readily disintegrate and therefore the analysts do not usually find them during analysis time. Yet they are present in most samples and are an integral part of the various processes in the aquatic environment. Liquid chromatographic methodology for the determination of organic acids in environmental samples will be developed. The preferred mode will be identified and applied to pulp mill effluent analyses.

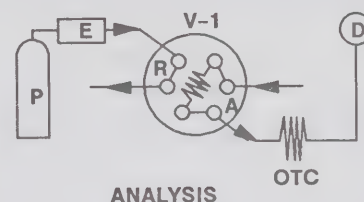
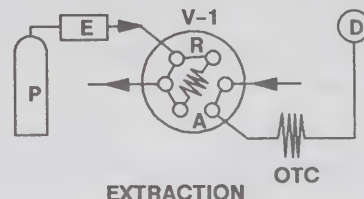
Development of extraction, pre-concentration and injection techniques

The extraction and recovery of organic contaminants is a critical and often limiting step in analysis schemes used to identify and determine organic pollutants. The use of supercritical fluids for analytical extractions can provide a powerful alternative to traditional extraction techniques. Supercritical fluid extractions can be performed at low temperatures and usually no pre-concentration procedures are required, thus reducing the potential for loss of analytes and possible thermal degradation.

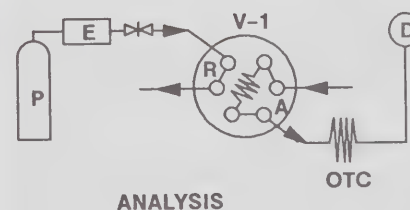
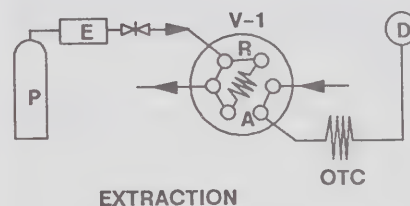
Large sample extraction technology, developed within the Analytical Chemistry Project, has become a routine pre-concentration method for the determination of "target compounds" at parts-per-trillion levels. The technology was accepted by the "Four Parties" administering the Niagara River Toxics Management Plan as the method to be used. The technology has been applied successfully in Great Lakes surveillance toxics monitoring. The current study is devoted to the development of the large-sample extraction systems suitable for use with a variety of environmental aqueous matrices and to integrate the pre-concentration technology with improved "cleanup" and analytical procedures.

The flow injection analytical system (FIA), developed by the Project, is optimizing the effectiveness and economy of environmental laboratories and environmental monitoring. FIA methods for Mg, Ca, Ba, Na, K, NH_4 , NO_3^- , NO_2^- , PO_4^{3-} , CN^- , alkalinity and acidity are now used on a routine basis. An automated robot system has been developed for presenting large numbers of samples to the FIA system. In the final version, it will handle entire strings of operations required for the analysis (i.e. sample identification, delivery to the analyzer, operation of the analyzer, data collection, calculation of the results, statistical evaluation and storage of the data).

A. LEACHING PROCESS



B. STEADY-STATE EXTRACTION



Schematics of the leaching (A) and steady-state extraction (B) illustrating supercritical fluid extraction-high resolution gas chromatography interfacing technique (SFE-HRGC). P, high pressure pump; E, extraction vessel; V1, 6-way switching valve; V-2, on/off valve; A, accumulator; d, detector; OTC, open tubular column; R, restrictor.

Study Leaders: B.K. Afghan,
D.H.J. Anthony, V. Cheam, S.A. Daniels,
H.B. Lee, F.I. Onuska, B.F. Scott, J.P. Sherry

Project Team: J.F. Lechner, K.A. Terry,
R.J. Wilkinson

Recent publications

Cheam, V. and E. Xue Li. 1988. Ion chromatographic determination of low level Cd (II), Co (II), and Mn (II) in water. *J. Chrom.* 450: 361-371.

Lee, H.B. 1988. Perfluoro and chloro amide derivatives of aniline and chloroanilines--their formation and gas chromatographic determination by mass selective and electron apture detectors. *J. Chromatogr.* 457: 267-278.

Scott, B.F. and F.I. Onuska. 1989. Analysis of polychlorinated biphenyls by dual column gas chromatography. NWRI Contribution No. 89-85.

Sherry, J.P., J. ApSimon, L. Collier, B.K. Afghan and P. Albro. 1988. Radioimmunoassay for the detection of polychlorinated dibenzo-p-dioxins in environmental samples: method description. NWRI Contribution No. 88-73.

Onuska, F.I. 1989. Techniques and procedures for preparation of aquatic samples for chromatographic analysis. *J. High. Resolut. Chromatogr.* 12: 4-11.

Sekerka, I. and J.F. Lechner. 1988. Determination of alkalinity of water by FIA with conductometric detection. NWRI Contribution No. 88-68.

Sekerka, I. and J.F. Lechner. 1988. Determination of acid neutralizing capacity of water and related problems. *Int. J. Environ. Anal. Chem.* (in press).

Regulation on Tributyltin

Agriculture Canada has recently announced a limited ban on tributyltins (TBT) used as antifoulants for ship hulls. The regulation prohibits the use of tributyltin on vessels less than 25 m in length. For vessel larger than 25 m, there will be a maximum daily release rate of 4 micrograms of tributyltin per square centimetre of hull surface. The regulation is similar to the ones adopted by France and England, and is identical to U.S. regulations. It came after several years of research done at NWRI on the occurrence of TBT in water, fish and sediments, and on the degradation and persistence of TBT in water and sediments.

COMING EVENTS

October 17-18, 1989. Workshop on the Mackenzie Delta: Environmental Interactions and Implications for Development to be held at the National Hydrology Research Centre, Saskatoon. This workshop will be interdisciplinary in nature with both invited and submitted presentations covering a range of topics dealing with the Mackenzie Delta ecosystem. The number of participants will be restricted to a maximum of 60 in order to encourage dialogue. There will be no registration fee for this workshop. The researchers and managers planning to contribute should submit a 300-500 word abstract, by September 1, 1989, to the Scientific Information Division, National Hydrology Research Institute, Environment Canada, 11 Innovation Boulevard, Saskatoon, Saskatchewan S7N 3H5. For further information, contact Brenda Doell at (306) 975-4022, or Simon Ommanney at (306) 975-5751. FAX: (306) 975-5143.

February 13-14, 1990. Workshop on Applications of Remote Sensing in Hydrology. This workshop will be held at the National Hydrology Research Centre in Saskatoon. Session 1, "Hydrologic Models", will concentrate on applications of satellite data in hydrological watershed models and will include sessions on means of increasing the utility of satellites for hydrological modellers. Session 2, "Microwave Hydrology", will emphasize the benefits of microwave remote data collection for hydrological monitoring, modelling and forecasting on watershed and global scales. Please submit abstracts of 300-500 words, before September 30, 1989, to Dr. Geoff Kite, (306) 975-5687, or Dr. Anthony Wankiewicz, (306) 975-5143, National Hydrology Research Centre, Environment Canada, 11 Innovation Boulevard, Saskatoon, Saskatchewan S7N 3H5. FAX: (306) 975-5143.

About NWRI

Environment Canada's National Water Research Institute (NWRI) conducts a national program of original research and development in the aquatic sciences, in partnership with the international freshwater science community. The twin goals of the Institute are to advance scientific understanding of national and international water issues important to Canada and to develop knowledge and authoritative expertise on these issues that can be used by Environment Canada to influence decisions affecting the wise management of Canada's water resources.

Research at NWRI is conducted within multidisciplinary projects, each focusing on a priority issue. Projects are grouped within three branches, the Lakes Research Branch, the Rivers Research Branch, and the Research and Applications Branch. Current long-term research priorities include: toxic chemicals in the Great Lakes and the St. Lawrence River; exchange of toxic contaminants between air, water, sediments, and biota; underground contamination; pesticide contamination in rivers; acid rain; lake rehabilitation; and aquatic monitoring, ecotoxicology, and risk prediction methodologies.

NWRI Digest

The NWRI Digest is the quarterly public newsletter of the National Water Research Institute, Conservation and Protection, Environment Canada. Suggestions, comments and further enquiries concerning newsletter items are welcomed. Please write to the Editor, NWRI Digest, National Water Research Institute, P.O. Box 5050, Burlington, Ontario, Canada L7R 4A6.

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LRTAP PROGRAM — PAST, PRESENT AND FUTURE

Formal planning for the aquatic portion of a federal LRTAP program commenced as an intensive exercise for a multi-departmental scientific committee in which the Department, then called Fisheries and Environment, took part. After much discussion and negotiation, the program was implemented in 1981 and, with iteration and revision, is reaching the end of a major phase in the development of the scientific understanding of lake acidification.

INSIDE

- Lead Concentrations Decline in the Lower Great Lakes
- Water Quality Models
- Tainted Fuel Incident
- Athabasca River Study: Update
- NWRI/Centre Saint-Laurent Collaboration on the St. Lawrence River
- Updating PPWB Water Quality Monitoring Program
- NWRI Involvement in CEPA Priority Substances Assessment
- Laboratory Association Update
- Sediment-Water Interactions Project
- Link Between Work and Community Involvement
- Kids Summerfest
- CSS Limnos in Montreal for Environment Week

The LRTAP program defined a management structure to maintain coordination, project approval and funding, and to ensure the finalization of reporting as required by the overseeing Research and Monitoring Coordinating Committee (RMCC). Inter-departmental program coordination was located at the Atmospheric Environment Service, whereas coordination of the aquatic effect components was lodged at NWRI under the direction of F.C. Elder. Following Mr. Elder's retirement, this position has been occupied by Dr. D.S. Jeffries.

As invariably occurs in Canadian national programs, there is a tendency for a program to become highly regionalized. This happens in management and program delivery as the regional conditions come into play and modify the central themes as defined at the national level. This took place to some extent in the LRTAP program and NWRI assembled an informal working group to ensure that the final synthesis would both conform at the national level and would allow smooth synthesis, interpretation and reporting of data. This group consisted of regional representatives from across the country, including provincial agencies, together with representation from the Department of Fisheries and Oceans. At the core of the group were a number of NWRI scientists who formed a focus and a resource for the discussions of the group. In this way, all pertinent data were lodged in the NWRI computer, and edited by NWRI

staff. Processing of the data, parameters to be used, and subdivision into geographical regions were by the combined agreement of the working group. Data were processed through RAISON, a data management and selective modelling system. This system was developed by NWRI and has been utilized by staff to predict the results of a range of sulphate control options, including those recently proposed by U.S. President Bush. Results have already been forwarded to the RMCC Report Writing Team, while a detailed technical report will be prepared by the informal working group.

It is now quite clear that major progress is being made in the control of sulphate emissions in the U.S. and Canada. The predictions of the beneficial effects to be derived from present and future controls have been made and only time will tell whether or not the predictions are correct. It would therefore appear that the future LRTAP program will be one of monitoring to corroborate that reductions are being achieved and to address emerging LRTAP issues such as nitrogen oxides. It is assumed that, through guidance to the regions and continuation of the Turkey Lakes monitoring program, NWRI will continue to be deeply involved.

R.L. Thomas
Senior Scientist
Rivers Research Branch



RESEARCH NEWS

Lead Concentrations Decline in the Lower Great Lakes

Analyses of surface waters in lakes Ontario and Erie have revealed that dissolved lead concentrations are an order of magnitude lower than those reported in 1986. The samples were collected in August 1987 utilizing "clean-sampling" and "clean-lab" technologies in a collaborative effort involving scientists from the Lakes Research Branch (NWRI), the University of California's Institute of Marine Sciences, and Lawrence Livermore National Laboratory and the Moss Landing Marine Laboratories (California). The application of these new methods, which minimize contamination during sampling and analysis,

explains the apparent dramatic decline. Average concentrations in this preliminary reconnaissance were 16 nanogram/L in Lake Erie and 6 nanograms/L in Lake Ontario. Higher values were found in the western basin of Lake Erie (28 ppt) and in Hamilton Harbour (60 ppt). These low concentrations in the dissolved phase may indicate that processes incorporating lead into or onto biological or mineralogical material are extremely active relative to processes reversing this trend, or that inputs to the open lake epilimnions are low during summer.

Stable lead isotope analyses of these samples suggested that the sources of lead in Lake Ontario were dominated by aerosols from the Toronto area, while they were dominated by aerosols typical of U.S. urban areas in southwestern Lake Erie. These results will be corroborated over the next field season and the samples will be analyzed in the new "clean-lab" facilities recently installed at NWRI.

Reference

Flegal, A.R., J.O. Nriagu, S. Niemeyer and K.H. Coale. 1989. Isotopic tracers of lead contamination in the Great Lakes. *Nature* 339: 455-458.

Water Quality Models

The Commission of the European Community is in the process of organizing a workshop on acidification processes in remote lakes. In recognition of NWRI's expertise in watershed acidification modelling, the workshop organizers invited staff from the Rivers Research Branch to review several models for potential application to remote mountain lakes. The results have been released recently.

Drs. W.G. Booth and D.C.L. Lam have

prepared an extensive review of recent (1978-1988) water quality models developed for predicting the impacts, pathways, fate and effects of nutrient and toxic chemicals in freshwater systems. The principal characteristics and applications of 38 nutrients and 35 toxic chemical models are summarized in a table format, which will allow researchers and managers to quickly review the availability of models

suitable for specific water quality concerns.

References

Booth, W.G. and D.C.L. Lam. 1989. Freshwater ecosystem water quality modelling. NWRI Contribution 89-63.

Jeffries, D.S., D.C.L. Lam, A.G. Bobba and W.G. Booth. 1989. Modelling acidification processes in remote lakes. NWRI Contribution 89-114.

Tainted Fuel Incident

Last May, a series of articles published in the *Toronto Globe and Mail* suggested that tainted fuels were imported in Canada. According to the reports, significant quantities of fuels, deliberately contaminated with hazardous waste materials, such as PCBs and other chlorinated compounds, were imported into Canada from the United States. A massive investigation was mounted by Environment Canada,

in collaboration with other federal and provincial agencies, to circumscribe the extent and nature of the problem. Staff of the Research and Applications Branch provided assistance to this effort in the area of analytical chemistry and quality assurance. Dr. B.F. Scott contributed his expertise in the selection of the methods to be used for the analysis of tainted fuel samples and, in cooperation with the National

Water Quality Laboratory, carried out the analysis of some 80 samples for PCB congeners and other organochlorine substances. Members of the Quality Assurance Project designed and conducted a special inter-laboratory quality assurance study aimed at ensuring the comparability of the data generated by the various laboratories participating in the analysis of fuel samples.

Athabasca River Study: Update

The Rivers Research Branch (RRB) has received funding from the federal Panel on Energy Research and Development (PERD) for a five-year project on the lower reaches of the Athabasca River in northeastern Alberta. This region has two existing tar sand plants which produce synthetic crude oil, and a third plant is planned. Dr. E.D. Ongley, Director of RRB, is the program manager. The large study will involve more than 15 scientists and technicians from RRB and will be coordinated by Drs. R.A. Bourbonniere and B.G. Brownlee.

Following initial discussions in January with Alberta Environment and Environmental Protection, Western and Northern Region, a detailed proposal was prepared. The study design included assessment and prediction of aquatic effects resulting from synthetic oil production. The proposal was presented in Edmonton, Alberta, in May to interested federal and provincial agencies, as well as industry and native representatives. This meeting initiated the process of discussion and coordination between study scientists and government, industry, and private organizations to ensure that broader concerns will be addressed to the greatest extent possible.

Since this study was first proposed, the impact of new and expanded pulp and paper mills in the Athabasca basin has

emerged as a major concern, particularly for downstream constituencies such as Wood Buffalo National Park in the Northwest Territories (NWT). RRB has been involved in the design of a water quality monitoring program for the Slave River (Alberta/NWT), which was discussed at a workshop in Yellowknife, NWT, in late June. RRB will also provide input for the federal Technical Working Group which is involved with the environmental impact assessment study for the proposed Alberta-Pacific pulp mill.

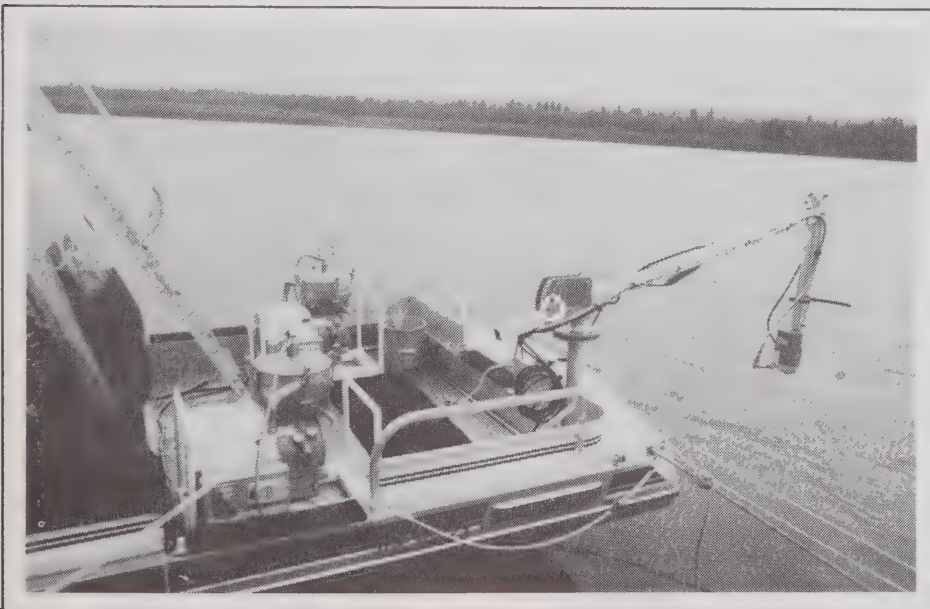
A reconnaissance survey was carried out in August with two newly acquired boats specially equipped for river travel and sampling. Fish were collected in the vicinity of the tar sand plants and will be analyzed for polycyclic aromatic compounds and metabolites. Water, suspended sediments and bed sediments were sampled between Fort McMurray and the Athabasca Delta, and in the Peace and Slave rivers. Water Quality Branch (WQB) personnel from Western and Northern Region joined RRB for collaborative work on sampling and extractive methods to help design the WQB monitoring program for the Wood Buffalo National Park. Water and sediment extracts will be analyzed during the winter and ecotoxicological testing on water and sediment samples will also be carried out.

Updating PPWB Water Quality Monitoring Program

From August 8 to 10, 1989, staff of all three research branches of NWRI attended a workshop to assist in the development of recommendations for updating the water quality monitoring program of the Prairie Provinces Water Board (PPWB). NWRI's participation was requested by the Water Quality Branch (WQB), Western and Northern Region, Regina, who will subsequently coordinate presentation of the results to the PPWB's Committee on Water Quality. The WQB has undertaken regular monthly sampling at 11 interprovincial river sites on behalf of the PPWB since the early 1970s. It has regularly presented arguments that PPWB's specific mandate would be better served if the program were to incorporate new and emerging monitoring and assessment techniques being developed and tested by a number of research and operational agencies, including NWRI. Areas of particular interest are toxic chemicals, suspended sediments and biological methods. A major program revision, developed with NWRI assistance, had been proposed by WQB in early 1988, but few changes resulted at that time. The Committee on Water Quality will now reconsider the proposal. Through this workshop, NWRI scientists have ensured that the proposed revisions to the program will reflect the latest developments in monitoring and assessment techniques.

NWRI/Centre Saint-Laurent Collaboration on the St. Lawrence River

This summer, five inter-related research projects were carried out on the St. Lawrence River during a three-week cruise on the Canadian research vessel *Limnos*. The projects are representative of the cooperative studies that NWRI and the Centre Saint-Laurent have planned to support *Plan d'action Saint-Laurent*. Some of the studies also involve the Institut
Continued on page 4



Sampling boom and centrifuges used to collect water and suspended sediment samples during reconnaissance survey of the lower Athabasca River in August 1989.

Continued from page 3

Maurice-Lamontagne of the Department of Fisheries and Oceans. The research projects included the reconnaissance of optimal sites for using freshwater and marine mussels as monitors of contaminant inputs and trends; a study of the physiological effects of effluents on selected mussel populations; the investigation of spatial and temporal concentrations of or-

ganochlorine compounds in water and suspended sediments, from Lake Ontario to the mouth of the Saguenay River, which was initiated four years ago; a study on the relationships between current speed/direction and turbidity in the turbidity maximum zone of the upper estuary; and the mapping of fine-grained modern sediments in the shallow (less than 10 m) zones of

the upper estuary where potentially contaminated sediments are deposited, at least temporarily.

The five projects focus on gaps in knowledge of the current state of this unique system with respect to contaminant transport, fate and effects. New techniques and instruments are used to quantify processes in this complex environment.

NWRI Involvement in CEPA Priority Substances Assessment

As part of the implementation of the Canadian Environmental Protection Act (CEPA), which was proclaimed in June 1988, the first Priority Substances List was published in the February 11, 1989 issue of the *Canada Gazette Part I* under the authority of the Minister of the Environment. As set out in the legislation, substances or group of substances enumerated in the list shall be assessed, whether they are toxic or capable of becoming toxic, in order to establish if regulatory control actions under CEPA are warranted. The term "toxic" under CEPA is given a definition which goes beyond the traditional one as it addresses the ability of a substance to enter the environment in quantities or under conditions that have or may have adverse effects on the environment, human life or health. With its 44 entries, the Priority Substances List has set the agenda for the next five-year period within Environment Canada (EC) and Health and Welfare Canada (HWC) with respect to hazard assessment of existing chemicals.

In response to a request for the participation of NWRI staff to these efforts, Dr. R.J. Maguire, Rivers Research Branch, has been selected to act as task

leader for the assessment of organotin compounds, and Dr. J.O. Nriagu, Lakes Research Branch, will serve in the same capacity for the assessment of chromium and nickel and their compounds. Task leaders are responsible for the planning and coordination of the efforts of task groups made up of individuals drawn from various government agencies, particularly EC and HWC. The work of a task group is focused on the preparation of a CEPA assessment report on the health and environmental hazards of the substance(s) assigned to the group.

Effluents from pulp mills using bleaching processes figure among the substances entered in the first Priority Substances List. As part of the work currently under way to assess the health and environmental hazard of various substances captured under this entry, A.S.Y. Chau and Dr. B.K. Afghan, Research and Applications Branch, have contributed their expertise to assist the assessment task group in the gathering and critical review of relevant analytical chemistry information and data.

Various management aspects of EC and HWC assessment activities fo-

cused on CEPA Priority Substances List are coordinated through an interdepartmental subcommittee chaired by Environment Canada, and where Dr. J. Lawrence, Director of the Research and Applications Branch, serves as the NWRI representative.

Proceedings of the CEPA Science Forum organized by NWRI and held at CCIW last February have recently been published for distribution to participants and other interested persons. The forum brought together scientists and science managers from government agencies, universities, the private sector and public interest groups to address the science needs that will arise in Canada in the coming months as part of the assessment of CEPA Priority Substances. The proceedings contain the text of the presentations given at the forum and a summary of the discussions that took place in workshop and plenary sessions. Those interested in obtaining a copy of the proceedings should contact the Director's Office, Research and Applications Branch.

Reference

Canadian Environmental Protection Act. Proceedings of the Priority Substances Science Forum, February 22-23, 1989, CCIW, Burlington, Ontario.

Laboratory Association Update

The Canadian Association of Environmental Analytical Laboratories (CAEAL) was officially incorporated on June 1, 1989. The interim Board of Directors, chaired by Dr. J. Lawrence, Director of the Research and Applications Branch, held its second meeting

on June 7, 1989, in Quebec City. An application for funding under the Technology Outreach Program has been submitted to Industry, Science and Technology Canada. Brochures advertising CAEAL will be available shortly, and a membership drive will be

launched. Mechanisms to establish relations with other professional associations are presently being developed. Negotiations with the Standards Council of Canada regarding the accreditation program are continuing.

PROJECT FOCUS

SEDIMENT-WATER INTERACTIONS PROJECT

Sediments deposited in lakes or oceans are generally derived from land. In addition to particles of terrestrial origin, bottom sediments also contain materials precipitated from chemical and biological processes occurring in water. Inputs of solids or dissolved materials, introduced as a result of human activities, will disrupt the chemical equilibrium between bottom sediments and overlying waters, as well as the living conditions of the biota in sediments.

Sediments can often provide a good source of information on pollution because they offer a continuous record of past episodic pollution events. This characteristic is due to the ability of solid particles to adsorb different metals and organic compounds, even at very low water concentrations. Many persistent contaminants entering the environment become attached to particles in the water and are transported into lakes and oceans, where they eventually settle. This process accelerates the removal of contaminants from water. On the other hand, through the same process, bottom sediments can also be a source for contaminants. Under certain conditions, contaminants are released into the overlying water or are taken up by sediment biota and cycled through the aquatic system. Biota in contact with contaminated sediments may experience physiological and reproductive problems, thus inducing other ecological impacts.

Contaminants deposited in bottom sediments may persist long after the original sources of contamination are eliminated. The cycling of sediment contaminants through the aquatic environment is controlled by many abiotic and biotic processes. These include the migration of contaminants through sediment pore water into the overlying water column, transport of contaminated sediment particles by resuspension through currents and bioturbation, bioaccumulation, biodegradation and biodeposition.

Processes governing the pathways of

sediment contaminants are not fully understood. Each pathway needs to be quantified to assess its impact on the health of the aquatic ecosystem and to identify pathways which can be controlled. The research program of the Sediment-Water Interactions Project is carried out to obtain information on these processes in order to produce realistic predictive models of contaminant behaviour in sediments and at the sediment-water interface, and to recommend proper procedures for remediation of contaminated sediments.

Abiotic process studies

The Great Lakes are predominantly supplied with fine-grained sediments. Fine particles provide a larger surface area for adsorption of different contaminants and therefore their dynamics play an important role in the transport of sediment-associated contaminants. Monitoring the movement of contaminated sediments and residence time in certain zones of rivers and lakes requires new techniques. Artificial tracers, particularly cesium silicate, were tested as tools for investigating the transport of fine sediments. In the Toronto waterfront area, the tests showed that silt-size material discharged from the Humber River in the spring was initially deposited close to the river mouth, but was subsequently transported along the western side of Humber Bay to the deep offshore waters of Lake Ontario. As this pilot study was successful, the technique will be used to comprehend the significance of contaminant inputs from the Humber River and other sources along the Toronto waterfront, and the transport of contaminated fine-grained particles in other areas of the Great Lakes.

Specially designed sediment traps were used to estimate the settling and resuspension fluxes of bottom sediments in lakes Erie and Ontario. During winter, in the central basin of Lake

Erie, the settling flux was greatest at 20 cm above the bottom. The flux decreased by 50% at 1 m and by 99% at 7m. The high settling rates near the bottom suggest a high resuspension rate and therefore a strong interchange of sediments and associated contaminants between the sediment water interface and the first few metres of the water column.

Historical trends of sediment contamination were determined using sediment dating by radionuclides and concentration profiles of contaminants. Natural burial of contaminated sediments with cleaner material is occurring in a few areas of the Great Lakes. For example, considerable decrease in lead concentrations in surficial sediments of lakes Erie and Ontario has resulted from the decrease in uses of leaded gasoline in North America.

Biotic process studies

Contaminants present in sediments can alter the benthic community structure, either directly or indirectly, by producing toxic effects on the water biota which have occasional contacts with the sediments. It is often difficult to demonstrate these effects in the natural environment because the heterogeneous nature of the geochemical and sedimentological regime can also be responsible for benthic community structure differences among sites. Biological effects of sediment contamination were demonstrated using sediment community structure data from the Detroit River. A statistical clustering technique was used to determine similarities among different areas on the river bottom. Clear boundaries could be established on an impacted area, and several parameters could be clearly identified as being responsible for the impact on the benthic community in this area. This type of impact analysis will prove useful in choosing the sites which need remediation in the Great Lakes and other freshwater systems.

The uptake of different organic contaminants in sediments by benthic invertebrates was also studied. In one of the experiments, oligochaete worms were used to determine uptake and depuration rates of radio-carbon labelled 2,4,6-trichlorophenol. The uptake data, expressed as ^{14}C activity per mg of worms, suggested a constant rate of accumulation for approximately 35 days, followed by reduced uptake until termination of the experiment at day 55 (see figure). The depuration process appears to be generally slower than the uptake. Our studies indicated that different organic contaminants have specific rate constants for both processes. These rates can be affected by physico-chemical conditions at the sediment-water interface, e.g., concentration of dissolved oxygen and temperature. The results will allow to predict the cleanup rates of aquatic environments after the elimination of external pollution sources.

Remedial/assessment studies

Placement in confined disposal facilities (CDFs) constructed along the shoreline is the only disposal technique currently available for dredged contaminated sediments in the Great Lakes basin. A summary of the dredging and disposal history, present conditions and vegetation communities at the CDFs located on the Canadian side of the Great Lakes was prepared. Sedi-

ments, vegetation and earthworms were sampled from 11 disposal sites, and analyzed for metals and organic contaminants. The concentrations of cadmium, chromium, nickel and zinc in vegetation exceeded those in urban foliage at several sites. Cadmium, copper and zinc were the only metals which appeared to bioaccumulate in the plants growing on the CDFs. These metals were accumulated to various degrees by different plant species. Sedges showed greater concentrations than any other plants. The concentrations of PCBs and PAHs in the vegetation were similar to those at control sites. The analyses of the rest of the collected samples from the CDFs are under way. The results of the study will be used to make recommendations on long-term management of CDFs in order to prevent the release of contaminants into the ecosystem.

A group of project scientists conducted a comprehensive study of sediment-water interaction processes at the mouth of the Spanish River, Lake Huron, one of the Great Lakes' Areas of Concern. Problems at this area include elevated concentrations of sediment contaminants, in particular nickel and copper, and low benthic fauna density and diversity. A strong negative correlation exists between benthic fauna densities and concentrations of nickel and copper in the sediments.

Project Chief: A. Mudroch

Study Leaders: J.P. Coakley, S.R. Joshi, E. Nagy, T.B. Reynoldson, F. Rosa, A.J. Zeman

Project Team: J.A. FitzGerald, S.P. Thompson

Recent Publications

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Coakley, J.P., M.G. Skafel, R.G.D. Davidson-Arnott, A.J. Zeman and N.A. Rukavina. 1988. Computer simulation of nearshore profile evolution in cohesive materials. *Proc. IAHR Symposium on Mathematical Modelling of Sediment Transport in the Coastal Zone*, Copenhagen, Denmark, p. 290-299.

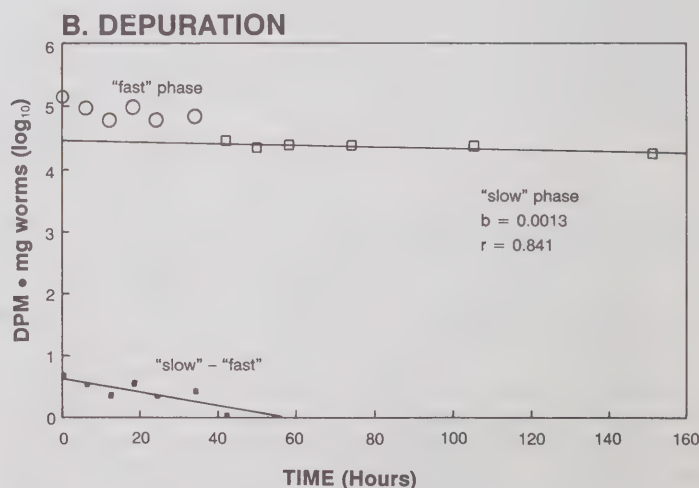
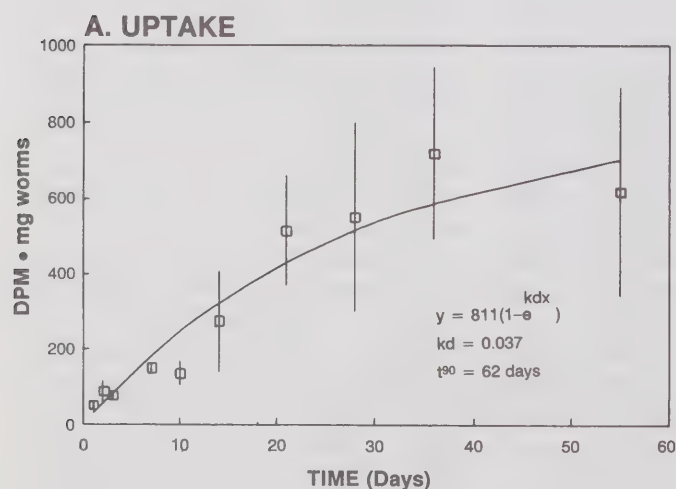
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^{14}C trichlorophenol uptake (A) and depuration (B) by aquatic oligochaete (DPM: desintegration per minute).

MEDIA NEWS

Link Between Work and Community Involvement

J.F. Ryan, Special Projects Coordinator in the Research and Applications Branch, has served as alderman in the City of Burlington since 1982. Presentations heard last February at the NWRI Symposium on Sustainable Development sparked Mr. Ryan's interest for this issue. He chose the opportunity of this year's Environment Week, in early June, to prepare a report on Sustainable Development for presentation to the Burlington City Council. The term "sustainable development" has been defined by the World Commission on Environment and Development, known as the Brundtland Commission, as "meeting the needs of the present without compromising the ability of future generations to meet their own needs."



Mr. J.F. Ryan, Research and Applications Branch.

Mr. Ryan's report and recommendations advocate for the incorporation of the concept of sustainable development as an integral part of the decision-making process and policies at the municipal government level, for instance in areas such as land use planning, economic development and waste management. It is Mr. Ryan's strong belief that Canada's success with delivering on the commitment to implement sustainable development requires the involvement of all levels of government in this country. Mr. Ryan's initiative was well received by the Burlington City Council and resulted in his appointment as the chairperson of a task force given the mandate to examine how recommendations contained in his report could be implemented.

Kids Summerfest

Last July, the Canada Centre for Inland Waters (CCIW) hosted a very successful, one-day children's summer festival for nearly 200 children and adults. The event, organized by NWRI and Dofasco Inc., was part of a large-scale children's festival sponsored by CBC-Television and CHFI-CFTR Radio in Toronto. During this entire summer festival, children from Southern Ontario were given the opportunity to visit the behind-the-scenes operations of government, business, art and entertainment facilities.

Children and parents enjoyed a two-hour boat cruise of Hamilton Harbour and the Windemere Basin. Dr. G.K. Rodgers, coordinator of the Hamilton Harbour Remedial Action Plan, was aboard the ship to discuss the pollution problem in the harbour and demonstrate water sampling techniques to the participants. Dr. Rodgers was assisted by Dr. S. Lesage, S. Painter, M. Fox and T. Mayer of NWRI, and by R.

Dobos of the Hamilton Naturalist Club. For most of the children, 4-12 years old, this was their first time on the harbour and most likely their first exposure to scientists.

Live entertainment in the CCIW auditorium followed the boat cruise. A puppet show, presented by the Toronto's Waterdown Production, a professional theatre group, focused on the importance of protecting our marshes and wetlands. Then, G. Paquette of the National Water Quality Laboratory, addressed the children as Professor Trout, the Talking Fish, much to the delight of the kids, who flocked to the microphone to challenge Professor Trout with difficult questions. The auditorium program concluded with a few songs by F.M. Boyce of NWRI while the audience tapped their feet and clapped their hands. A picnic staged on the grass outside CCIW was a perfect conclusion to the day.

CSS *Limnos* in Montreal for Environment Week

The Canadian Scientific Ship (CSS) *Limnos* was docked in Montreal Harbour on 6-7 June 1989. As part of Environment Week activities, guided tours of the ship were organized by NWRI for employees of Conservation and Protection, Atmospheric Environment and Canadian Parks Service, and Centre Saint-Laurent consultants. Visitors were given a brief overview of the research and monitoring programs carried on by the vessel and of the specialized scientific equipment used on board. The CSS *Limnos* is a general-purpose scientific vessel based at the Canada Centre for Inland Waters, in Burlington, Ontario. It sails throughout the Great Lakes and the St. Lawrence River on research and monitoring voyages mainly for NWRI, other elements of Environment Canada and the Department of Fisheries and Oceans.

◆ ◆ ◆ S T A F F N E W S ◆ ◆ ◆

A. Mudroch was appointed President of the International Association for Great lakes Research (IAGLR) for 1989/90 at its annual conference held in Madison, Wisconsin, last May. The association provides a unique forum for sharing research information on large lakes of the world through conferences and a journal. The implications of these research results on environmental conservation are also communicated by the association to governments on behalf of the research community. Over the years, NWRI scientists have been asked by the Board of Directors to serve as president, but this appointment is special. In 1968, Mrs. Mudroch came to NWRI as a political refugee from Czechoslovakia to work as a technician in a foreign land. She has made up for time lost in this relocation through her diligence and is now Chief of the Sediment-Water Interactions Project, Lakes Research Branch.

Dr. R. Bisson has been appointed as Science Liaison

Officer of the Research and Applications Branch. Dr. Bisson obtained his Ph.D. in Synthetic Organic Chemistry (natural products) from the University of Western Ontario. Between 1979 and 1988, he was employed with Environment Canada in what is now known as the Commercial Chemicals Branch. Dr. Bisson joined NWRI last July, following a 15-month stint with the Environmental Protection Branch of the Canada Oil and Gas Lands Administration, Ottawa.

The Rivers Research Branch is proud to report that two of its scientists have received meritorious distinctions recently. **Dr. S. Beltaos** of the River Modelling Project has been named a fellow of the Canadian Society of Civil Engineers. This distinction is awarded for excellence in engineering and services to the profession. **Dr. Y.K. Chau** has been elected to the Fellowship of the Chemical Institute of Canada by the Distinctions and Awards Committee of the Institute's Council.

COMMING EVENT

R.A. Vollenweider Lectureship in Aquatic Sciences. Dr. Charles R. Goldman, Professor of Limnology and Chairman of the Division of Environmental Studies, University of California, Davis, has been awarded the 1989 NWRI R.A. Vollenweider Lectureship. The prize is granted annually to an eminent scientist for his or her global contribution to the advancement of the aquatic sciences. Dr. Goldman will give his lecture on Wednesday, November 8, 1989 at 10:30 a.m. in the South Seminar Room, Canada Centre for Inland Waters, 867 Lakeshore Road, Burlington, Ontario. Everyone is welcome to attend the lecture entitled *Lake Tahoe: Limnological Research to Resolve Environmental Conflict*.

Think Recycling!



Pensez à recycler!

About NWRI

Environment Canada's National Water Research Institute (NWRI) conducts a national program of original research and development in the aquatic sciences, in partnership with the international freshwater science community. The twin goals of the Institute are to advance scientific understanding of national and international water issues important to Canada, and to develop knowledge and authoritative expertise on these issues that can be used by Environment Canada to influence decisions affecting the wise management of Canada's water resources.

Research at NWRI is conducted within multidisciplinary projects, each focusing on a priority issue. Projects are grouped within three branches: the Lakes Research Branch, the Rivers Research Branch, and the Research and Applications Branch. Current long term research priorities include: toxic chemicals in the Great Lakes and the St. Lawrence River; exchange of toxic contaminants between air, water, sediments and biota; underground contamination; pesticide contamination in rivers; acid rain; lake rehabilitation; aquatic monitoring; ecotoxicology; and risk prediction methodologies.

NWRI Digest

The NWRI Digest is the quarterly public newsletter of the National Water Research Institute, Conservation and Protection, Environment Canada. Suggestions, comments and further enquiries concerning newsletter items are welcomed. Please write to the Editor, NWRI Digest, National Water Research Institute, P.O. Box 5050, Burlington, Ontario, Canada L7R 4A6.

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Digest

WINTER 1990

NWRI AND THE GLOBAL GEMS/WATER PROGRAM

The Global Environmental Monitoring System (GEMS), under the aegis of the United Nations Environmental Program (UNEP), is a family of global data programs focusing on a wide variety of environmental issues. One of these, the GEMS/WATER program, is the first of its kind to address global issues of water quality through a network of some 350 monitoring stations in rivers, lakes, reservoirs and ground water on all continents. The GEMS/WATER program, managed jointly by the World Health Organization (WHO) and UNEP, has utilized the data banking facilities of the National Water Research Institute (NWRI) as its centre.

INSIDE

- Environmental and Biological Impact of Deltamethrin
- Simulation of Spills and Plumes
- Technology Transfer
- Knowledge-Based Approach to Regional Acidification Modelling
- New Analytical Methods
- Understanding and Forecasting Sediment Processes
- IJC Biennial Meeting
- Trees to Monitor Air Pollution
- The Contaminants Project
- The Hydraulics Project
- NWRI's Second Vollenweider Lectureship

As a WHO Collaborating Centre, NWRI has served as a focal point for water quality and water management information around the world.

In 1989, as a result of an international review of the GEMS/WATER program, experts from UNEP, WHO and NWRI proposed a significant change in objectives for the program. Traditional monitoring activities will be expanded to include a major effort in data interpretation and assessment, with a realigned global network focusing on:

- global baseline conditions;
- environmental trends detectable in river water quality at the regional and sub-basin level;
- global fluxes of chemicals from rivers into nearshore environments of regional seas and oceans.

A parallel development was the recent decision by the UNEP Governing Council at its June 1989 biennial meeting to identify water as one of its seven priority topics for action in the near to medium term. This decision of the Governing Council was strongly endorsed by the Canadian Delegation which argued that water must be regarded as the central theme for regional, national and international sustainable development activities.

The proposed realignment of the GEMS/WATER program is a key element of the UNEP water program, especially as the world prepares for the 1992 World Conference on Environment and Development. To secure UNEP and WHO concurrence to the

changes in the GEMS/WATER program, Drs. Daley and Ongley travelled to UNEP headquarters in Nairobi, Kenya, in November 1989. As a consequence, NWRI will be playing a much larger role in the management and implementation of the GEMS/WATER program. UNEP has agreed to a doubling of resources to the program. NWRI will be designated as a UNEP Global Collaboration Centre for Water Quality Assessment in recognition of the role NWRI will play in the new program. NWRI will also chair a new "Committee of Experts" which will advise on the scientific content of the program and oversee preparation of data reviews and assessments. Annual data summaries, biennial evaluations of specific global water issues and a global "State of the Environment" report on water quality every five years will be produced. Further, NWRI will participate in the development of a global water atlas scheduled for completion in late 1993, and the RAISON (regional analysis by intelligent systems on a microcomputer) expert system software, developed by NWRI and now used widely for water resource management, will be adapted for application to the GEMS global data base.

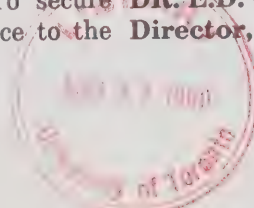
Although not well known, the GEMS/WATER program is one of the largest international programs carried out by Environment Canada as part of Canada's growing commitment to global environmental management.

DR. R.J. DALEY,
Chief, Science Liaison Division
DR. E.D. ONGLEY,
Director, Rivers Research Branch



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Environmental and Biological Impact of Deltamethrin

The management of ambient water quality is often based on the control of chemical sources so that observed levels of toxic chemicals in the aquatic environment are maintained well below concentrations at which any harm may occur. The increased use of new degradable pesticides, however, may force us to revise our approach to the management of ambient water quality. Studies in Prince Edward Island conducted in cooperation with Environmental Protection (EP) show that deltamethrin, an increasingly common insecticide, disappears quickly when sprayed on a pond. Deltamethrin, licensed for use on tobacco, pears, canola, mustard, potatoes, sunflowers, broccoli, cabbage, wheat and barley crops, has a half-life of about one hour. Further, its breakdown products disappear within 11 days. The complementary EP report documents that despite this

rapid degradation, massive mortality of invertebrates and some mortality of fish occur. The management of a chemical which is unlikely to be detected in the ambient environment, but whose effects are both sudden and dramatic, must be based on strict regulation of usage. The EP report establishes the utility and effectiveness of the regulatory implementation of 100-metre setbacks from surface waters during agricultural spraying.

References

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Ernst, W.R., R.J. Maguire, J.H. Carey, G.R. Julien, J.H. Hart, R.J. Tkacz and H.-B. Lee. 1989. The fate, persistence and biological impacts of deltamethrin applied directly to an agricultural pond system and the protection from deposit afforded by a 100-metre setback. EP Surveillance Report EPS-5-AR-89-1.

Simulation of Spills and Plumes

A fast graphical simulation procedure has been developed to show, on microcomputers, the trajectory of spills or effluent plumes in coastal locations with along-shore currents. Based on meteorological data and current measurements from fixed and movable devices, a simple linear impulse response function is applied to relate current to wind history. The procedure offers a number of display

options for the plume or patch generated by continuous or instantaneous releases of the pollutant. It is being incorporated into the RAISON expert system for spill analysis for such locations as the Great Lakes.

Reference

Wong, I., D.A. Swayne, C.R. Murthy and D.C.L. Lam. 1989. Fast graphical simulations of spills and plumes for application to the Great Lakes. *Ecol. Model.* 47: 161-173.

Technology Transfer

The 3M Company in St. Paul, Minnesota, has been developing a water-soluble masking tape and has asked the advice of Dr. D.L.S. Liu of the Rivers Research Branch on the assessment of its toxicity and biodegradability. As a result of the information provided, 3M has decided to use two toxicity screening methods recently developed in the Rivers Research Branch for their tier-1 screening tests.

References

Liu, D.L.S., Y.K. Chau and B.J. Dutka. 1989. Rapid toxicity assessment of water-soluble and water-insoluble chemicals using a modified agar plate method. *Water Research* 23: 333-339.
Liu, D.L.S. 1989. A rapid and simple biochemical test for direct determination of chemical toxicity. *Toxicity Assessment* 4: 399-404.

Knowledge-Based Approach to Regional Acidification Modelling

A knowledge-based systems approach has been used in selecting watershed acidification models for the assessment of aquatic resources at risk in Eastern Canada. Instead of choosing only one model and discarding others, the approach utilizes the most appropriate model for each case study. This requires both quantitative and qualitative judgement for the selection of the proper model for each lake or watershed. Results obtained in this manner were compared with observed data for acid neutralization capacity (ANC). Mean relative errors of 22.0% and 19.1% were found for southern Quebec and New Brunswick, respectively. These errors for the combined model results were within those of the observed data range and were less than those of the individual model results; the uncertainties were greater for higher sulphur dioxide loads. Currently, this knowledge-based approach is being operated in the RAISON expert system and applied to other regions in Eastern Canada for different loading scenarios. Results will be used in the 1990 LRTAP National Assessment.

References

Lam, D.C.L., D.A. Swayne, J. Storey and A.S. Fraser. 1989. Watershed acidification models using the knowledge-based systems approach. *Ecol. Model.* 47: 131-152.

Lam, D.C.L., D.A. Swayne, A.S. Fraser, J. Storey and I. Wong. 1989. A knowledge-based approach to regional acidification modelling: a case study of New Brunswick, Canada. In *Regional Acidification Models, Geographic Extent and Time Development*, Kamari et al. (eds.), p. 213-226. Springer-Verlag, Berlin, FRG.

New Analytical Methods

New and improved analytical methods are developed by staff of the Research and Applications Branch in response to specific needs for water pollution research and monitoring programs.

A simple method has been developed to couple the supercritical fluid extraction of environmental samples on-line with high resolution capillary column gas chromatography and electron capture detection. The method was tested with PCB-contaminated sediments. Factors affecting the extraction step, such as choice of the mobile phase, temperature and pressure, were investigated. Extraction efficiencies of up to 100% in less than 15 minutes were obtained.

Resin acids and some fatty acids are generally regarded as major contributors to the overall toxicity of pulp and paper mill effluents because of their high concentration and their individual toxicity. Until now, existing methods were not adequate for the measurement of these constituents in large volume effluents. Efforts to find a more sensitive analytical method have led to the development of a capillary column gas chromatography and electron capture detection technique. A 100-fold increase in sensitivity over existing methods is achieved using this new method. The novel approach of the method centres on the conversion of the constituents of interest into pen-

tafluorobenzyl ester derivatives and on the techniques used for the confirmation of the esters via mass spectrometry. Effluents from pulp mills using bleaching processes have been listed as priority substances under the Canadian Environmental Protection Act.

References

Onuska, F.I. and K.A. Terry. 1989. Supercritical fluid extraction of PCBs in tandem with high resolution gas chromatography in environmental analysis. *J. High Resolut. Chromatogr.* 12: 527-531.

Lee, H.B., T.E. Peart and J.M. Carron. 1989. Gas chromatographic and mass spectrometric determination of some resin and fatty acids in pulp mill effluents as their pentafluorobenzyl ester derivatives. NWRI Contribution 89-125.

Understanding and Forecasting Sediment Processes

Dr. B.G. Krishnappan, Rivers Research Branch, is investigating the dynamics of fine sediments, in particular the process of flocculation and its effects on transport and settling.

During the course of his studies, he has developed a field version of the Malvern analyzer, which is a laboratory instrument operating on the principle of light diffraction for the analysis of particle size. The investigation of flocculation processes requires that the particle size distribution of suspended sediments be measured without disrupting the floc structure. The fragility of the structure is such that only *in situ* measurements are useful. Assembly of the first field unit has been completed and initial performance testing indicates that the field instrument performs as well as the original laboratory version.

The construction of a rotating flume is also under way. The flume will be used to conduct experiments on the processes of flocculation, settling, consolidation, erosion and resuspension. Sediment-contaminant interactions will also be studied. Installation of the flume is anticipated before spring 1990.

IJC Biennial Meeting

Many NWRI scientists and managers attended the IJC Biennial Meeting on Great Lakes Water Quality, held in Hamilton, Ontario, October 10-13. The meeting consisted of formal presentations to the International Joint Commission from the Water Quality and the Science Advisory boards; presentations from a wide range of public interest groups and citizens; and workshops on environmental quality and human health, Remedial Action Plans and sustainable development. The Water Quality Board reported that the decline in contaminants in water, fish and aquatic birds

had stopped in the early 1980s and that there were no consistent trends in these concentrations. The present concentrations are still considered too high and will not ensure ecosystem health in the long term.

On the last day of the meeting, 150 people, including several IJC commissioners, toured CCIW. An overview of the research programs at NWRI was given by Dr. R.J. Allan, Director of the Lakes Research Branch. The activities of the Great Lakes Laboratory for Fisheries and Aquatic Sciences were described by the Director, Dr. J.M. Cooley.

Trees To Monitor Air Pollution

A collaborative team of researchers, involving scientists from the University of Stockholm and Dr. W.M.J. Strachan, Lakes Research Branch, has tested a new way to monitor air quality on a regional, sub-regional and site-specific basis. It involves the chemical analysis of pine tree needles. The use of coniferous trees has several advantages; not only can the same tree be sampled over many years, the tree can also be sampled for several age classes of needles to further assess the interannual variability.

The technique was first tested on Scotch pine needles from France,

Germany, Switzerland, Poland, Denmark, Sweden and Norway. The needles were analyzed for DDT, pentachlorophenol, PCBs and lindane. The high wax content of coniferous needles, particularly that of pine, seems to facilitate the adsorption of these lipophilic contaminants. Depending on the species chosen, it should be possible, in the northern temperate zone, to set up a sampling grid of appropriate density to characterize the global extent of these persistent contaminants.

Reference

Erickson, G., S. Jensen, H. Kylin and W.M.J. Strachan. 1989. The pine needle as a monitor of atmospheric pollution. *Nature* 341: 42-44.

THE CONTAMINANTS PROJECT

The current studies which comprise the Contaminants Project of the Rivers Research Branch are focused on resolving selected knowledge gaps concerning the occurrence, persistence and toxicity of priority contaminants.

Occurrence

Significant concentrations of PCBs and other chlorinated hydrocarbons have been found in dichloromethane of filtered Niagara River water at pH 12 after the water had been thoroughly extracted at pH 1. In samples from 43 dates in 1985–86, the contribution of the basic extract to the total concentration derived from acidic, basic and suspended solids extracts ranged from 0% for 31 of these chemicals to 100% for PCBs 15, 114 and 201, aldrin and p,p'-DDT. When the sums of concentrations of each chemical found in the Niagara River water in the acidic, basic and suspended solids extracts were themselves calculated, the basic fraction contributed 40% to the total concentrations of all chemicals and 48% if only PCBs were considered. Experiments with water from another source showed that some PCBs were recovered in dichloromethane extracts of basic filtered water which had previously been thoroughly extracted under either acidic or neutral conditions. These results indicate that concentrations of chlorinated hydrocarbons in the Niagara River water, determined by extraction solely at neutral pH, the usual technique, may be underestimated. This finding, which may have general applicability to freshwaters, may be the result of a strong association between a fraction of the dissolved lipophilic chemicals and dissolved organic matter in freshwaters, an association that is resistant to organic solvent extraction at acidic or neutral pH, but which is at least partially disrupted by extraction at high pH. This phenomenon of neutral lipophilic chemicals in basic extracts of filtered water after extraction at neutral pH has recently been confirmed by an independent laboratory. It is recommended that present methods of determination of such chemicals

be reviewed and, if necessary, changed to take into account any fraction which is only extracted under basic conditions. Although it is not widely used for neutral chemicals, the U.S. Environmental Protection Agency's base/neutral method, which employs initial extraction at pH >11, may be more appropriate than the more commonly used method of extraction at neutral pH.

Native unionid mussels have been evaluated as biomonitors for organic contaminants in the St. Lawrence River. Because mussels are large, abundant, sedentary, non-selective in terms of habitat, and easily standardized as to sex, age, lipid content, etc., they are ideal candidates for biomonitoring. Native mussels were collected from 17 stations in the St. Lawrence River between Lake Ontario and Trois-Rivières and from 3 stations in a major tributary, the Ottawa River. The mussels bioaccumulated the major organic industrial contaminants and pesticides of concern in these areas. Spatial distribution patterns for contaminants in mussel tissues generally reflected the known distribution of these compounds in bed sediments; they implicated Lake Ontario as the source of mirex and DDT derivatives and the Grass River (New York State) as a major source of PCBs. Congener-specific PCB analysis revealed that most PCBs persisted in resident mussels for several hundred kilometres downstream of the point source in a characteristic pattern, which differed from that occurring in locations remote from point sources. Concentrations of most contaminants in mussels from the Ottawa River were 50–75% lower than the lowest values reported for the St. Lawrence River. Biomonitoring with mussels has several potential applications. It may be used to complement or supplement traditional ambient water or sediment monitoring programs, primarily to provide information on bioavailability. It can also be used to define the impact zone of point-source pollution and to serve as a feedback mechanism for determining the effectiveness of pollution

control measures as they are implemented.

Leeches have excellent potential as screening organisms for chlorophenols in water because of their high bioconcentration capacities, slow elimination rates and inability to degrade these compounds. A study was undertaken to determine whether biomonitoring with leeches could be used to assess the impact on their receiving waters of two industrial point sources of chlorophenols in the Rainy River and Thunder Bay Harbour. Leeches could be successfully caged for on-site exposures of up to three weeks, and they accumulated chlorophenol concentrations 10–100 times higher than those in mussels, which are the most commonly used biomonitors. Concentrations of chlorophenols were elevated above pre-exposure levels in leeches caged over 100 km downstream of a pulp mill on the Rainy River, even though chlorophenols could not be detected in water or suspended solids. Tissue residues of chlorophenols in caged leeches also provided information on the origin, distribution and availability of chlorophenols discharged from a wood-preserving plant on Thunder Bay Harbour. Bioassays conducted on harbour sediment, using fathead minnows, burrowing mayflies and leeches, demonstrated that uptake and toxicity decreased with increasing distance from the plant. This study demonstrated that leeches are far superior to mussels as biomonitors for chlorophenols and that they can be successfully caged and used in routine monitoring wherever chlorophenol pollution is suspected.

Persistence

The pyrethroid insecticide deltamethrin sprayed on a pond in Prince Edward Island disappeared quickly from water, with a half life of about one hour. Major routes of degradation or dissipation were (i) chemical and photochemical conversion to inactive (2+2')-deltamethrin stereoisomers and (ii) hydrolysis with subsequent oxidation of products.

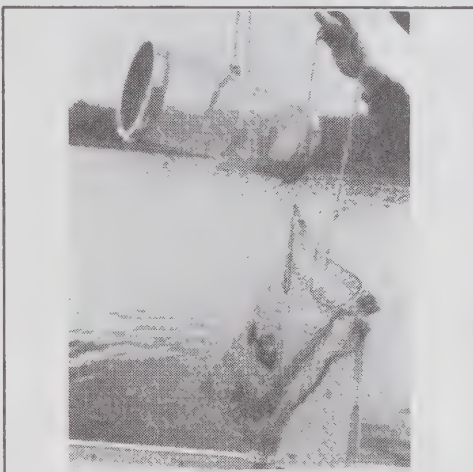
No residues of deltamethrin stereoisomers or any of the four major products sought were found 11 days after the spray. Laboratory experiments on the volatilization of deltamethrin formulations from sprayed water as opposed to subsurface-injected water indicated that volatilization from the surface microlayer was a very fast process that could be the major route of dissipation of deltamethrin (or any lipophilic pesticide) sprayed on a pond. Subsequent chemical investigation with an optically active chromatographic method indicated that parent deltamethrin (designated as isomer 1) in water is rapidly converted to isomers 2', 3' and 4' by sunlight photolysis and a dark chemical reaction. Since we have shown that isomer 3 is toxic to *Daphnia magna*, it appears that the isomerization noted above in the field is only a partial detoxication.

Toxicity

The detection of biochemical changes at the molecular and cellular level in organisms exposed to chemical contaminants may be the earliest and most sensitive indication of a toxic response. These changes may in turn be indicative of decreases in the survival, growth and/or reproduction at the population and community level. Measurement of changes in intracellular tissue concentrations of free amino acids (FAA) is used as a biochemical tool. Total concentrations of FAA have been shown to increase or decrease following exposure to toxic chemicals. FAA levels were measured in several tissues of mussels exposed in cages to water in some tributaries of the Yamaska River in Quebec. Results indicate that total concentrations of FAA increased above background or control levels in both mantle and adductor muscle tissues at sites im-

pacted by agricultural runoff and municipal or industrial effluent. These same sites were classified as poor to very poor in water quality using a biotic index for benthic invertebrate community health. These results are similar to those reported in other studies on freshwater organisms. They suggest that increases in total FAA in some tissues of freshwater bivalves may be indicative of generalized stress and may be a useful biomonitoring technique to assess toxicity from non-point source pollutants.

The use of nucleotide ratios and metallothionein induction is also being studied as indicators of stress in mussels exposed to cadmium, copper, zinc and tributyltin at 10/ μ g/L.



Caged leeches and mussels in biomonitoring study.

Preliminary results indicate that metallothionein induction decreases in the series Cd > Cu > Zn > tributyltin. A simple, rapid and sensitive technique has been developed for determining the toxicity to bacteria of both water-soluble and water-insoluble chemicals.

The procedure uses a direct agar-diffusing assay and a non-toxic carrier

solvent (dimethyl sulfoxide-glycerol). Test results are obtained within 3-4 hours. The method is suitable for both toxicity screening and structure activity studies.

Project Chief: R.J. Maguire

Study Leaders: R.A. Bourbonniere, Y.K. Chau, K.E. Day, D.L.S. Liu, K.R. Lum, J.L. Metcalfe, H.K.T. Wong

Project Team: S.P. Batchelor, C. Jaskot, A.M. Koffyberg, G.J. Pacepavicius

Recent publications

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Metcalfe, J.L. and A. Hayton. 1989. Comparison of leeches and mussels as biomonitors for chlorophenol pollution. *J. Great Lakes Res.* 15: 654-668.

Metcalfe, J.L. and M.N. Charlton. 1990. Freshwater mussels as biomonitors for organic industrial contaminants and pesticides in the St. Lawrence River. *Sci. Total Environ.* In press.

THE HYDRAULICS PROJECT

Research in the Hydraulics Project of the Research and Applications Branch focuses on the physical dynamics of water and its interaction with air, sediments, shore and man-made structures. Studies provide new knowledge for use by water resource managers and engineers in Environment Canada and elsewhere. This article highlights a few studies conducted in the Hydraulics Project: the transfer of toxics between air and water done in the new

gas transfer flume; the assistance provided to the Water Resources Branch (WRB), Environment Canada, in its role to document our water resources; and the provision of expert advice and laboratory facilities to external clients.

Gas transfer at air-water interfaces

Gas transfer at air-water interfaces is a complex process which plays an im-

portant role in geobiochemical cycles. In particular, the exchange of greenhouse gases (e.g., methane, carbon dioxide) is critical to fully understand the process of climatic change. There is also a vivid interest in the gas transfer of some high molecular weight organic compounds, which are of direct relevance for environmental and human health.

An air-tight recirculating gas transfer flume (GTF) has been designed and constructed in the Hydraulics Laboratory for mass (gas) transfer studies across the air-water interface as well as for studies related to wave mechanics and boundary layer turbulence in air and in water. The GTF can provide mean wind speeds from 1 m/s to 22.5 m/s and mean water velocities up to 0.50 m/s, with water recirculation possible in both directions. Wind-generated and/or programmable paddle-generated waves can be obtained in the flume. The test section is 32-m long and 0.76-m wide, while the water depth is designed to be 0.25 m and the height of the air duct is 0.60 m.

The system is equipped with high efficiency filters for air and water. At the end of each experiment, air and water in the GTF can be safely discharged through these filters.

There are three measuring stations at different fetches, each with glass windows on both sides of the test section.

Each station is equipped with appropriate instrumentation to do aerohydrodynamic and chemical measurements.

The transfer properties of hexachlorobenzene, an organochlorine fungicide, was examined using two experimental methods. The first was based on the decay of aqueous concentration of the fungicide after an initial addition and the second hinged on the approach to equilibrium of the aqueous concentration during steady addition of the contaminant. In both cases the wind tunnel was operated in a ventilated condition so that the air stream was essentially free of the fungicide. The methods were in close agreement over a wide range of wind speeds. Tests have also been conducted on several pollutants and the analysis of the data is in progress.

Support to WRB

Flow measurement structure for Milk River

The Milk River is a regulated, international river which flows through Montana, USA, and Alberta, Canada. The waters are shared by Canada and the USA, in accordance with the *Boundary*

Water Treaty of 1919 and a 1921 Order of the International Joint Commission. Satisfactory apportioning of the water requires that reliable discharge records be obtained at the hydrometric gauge at Eastern Crossing, Montana. The Milk River is a sand-bed stream. As a result, stage-discharge relationships are poorly defined and corrections to the discharge records, based on frequent discharge measurements, must be applied. The Hydraulics Laboratory was asked by the Water Survey of Canada, Water Resources Branch, Calgary, Alberta, to examine ways to improve the quality of the discharge records. Existing methods were reviewed and then mobile bed model tests were conducted. Results indicate that a three-dimensional, submerged weir has the best chance of success. Theoretical analysis and model testing show that the head-discharge relationships in the prototype is expected to be stable for heads greater than 0.75 m, which is equivalent to an average flow during the irrigation season of 15 m³/sec. For smaller heads, sediment deposition in the approach channel may vary the discharge coefficient sufficiently to render the head-discharge relationship unstable. Further tests are planned in order to examine the variability of the discharge coefficient at the lower flows.

Measurement of flow in streams with solid ice cover

Uncertainties in the measurement of stream flow during periods of ice cover have long been the concern of water resources data managers. The Water Survey of Canada is addressing this problem by examining flow measurement procedures and new equipment with technical assistance provided by the Hydraulics Project. Emphasis is placed on examining and testing acoustic flow meters, on review of performance characteristics of conventional current meters and associated systems, and on the development and implementation of a nationwide flow measurement program involving 36 different stream sites.

Suspended sediment sampler calibration

Suspended sediment is the dominant component of the total sediment load transported by alluvial streams. Accu-

rate measurement of suspended sediment concentration is important for a wide range of engineering and environmental problems. Recent emphasis on considering fine sediment fractions as a water quality parameter makes accurate sediment sampling more important than ever. The Water Survey of Canada uses about 600 suspended sediment samplers in its national program. Their calibration requires significant time and resources. To meet the requirements, the Water Survey of Canada, together with the Hydraulics Project, is establishing a comprehensive calibration strategy which will ensure that the necessary measurement accuracies are obtained.

Client studies

The specialized equipment and facility of the Hydraulics Laboratory are made available to external clients via cost recovery or joint venture agreements under a policy established by Environment Canada. Several important projects have been undertaken recently.

Windermere Basin model study

A physical hydraulic model study of the Windermere Basin was done at the request of Mar-land Engineering Ltd., agents for the Hamilton Harbour Commissioners. The Windermere Basin, located in the southeast corner of Hamilton Harbour, is the subject of a cleanup operation involving the dredging of contaminated sediments and disposal behind berms to be constructed in the basin. The functions of the basin, after dredging and reshaping with berms, will be to improve aesthetics and to trap incoming contaminated sediments before they enter the main part of the harbour. The distorted-scale physical model was designed to accomplish the following: to determine the hydraulic efficiency of the proposed settling basin; to investigate the effects and relative merits of spur dikes and vanes on improving the hydraulic efficiency of the basin; to determine the effect of a wide broad-crested weir at the outlet of the basin; to determine the effect of a sediment trap on the hydraulic efficiency of the basin.

Investigations of a non-standard Parshall flume

The regional municipality of York operates a Parshall flume, with non-standard flow conditions at the entrance, to measure sewage discharges in a trunk sewer. Such conditions, which are created by two upstream-impact baffles serving to dissipate excessive kinetic energy of the approaching flow, caused concerns about the applicability of the standard-rating curve to this facility. Consequently, the municipality of York commissioned the Hydraulics Project to study the accuracy of their flow measurement facility in a hydraulic mode. This study has been successfully completed and provided information on the effects of the impact baffles on the rating curve of the standard Parshall flume, response characteristics of the existing stilling well used for flume head measurements and corrective measures for flumes with high-velocity approach flows. The methodology developed in this study is generally applicable to investigations of malformed flow measurement structures sometimes encountered in municipal as well as industrial installations.

Breakwater design

Sandwell Swan Wooster Inc. was retained by Public Works Canada to design a rubblemound breakwater for a new marine project at Port Colborne, Ontario.

The marina breakwater is partially protected from Lake Erie waves by the existing outer harbour breakwater. Under design conditions, however, the outer breakwater is overtopped and a considerable amount of wave energy is transmitted toward the inner harbour and marina. At the request of Sandwell Swan Wooster Inc., the Hydraulics Laboratory conducted 1:30 scale physical hydraulic model tests of the outer breakwater to determine the design wave for the marina breakwater. Subsequently, two dimensional stability tests were run to determine the optimum cross-section of the marina breakwater. Waves were generated and analyzed using the National Research Council of Canada GEDAP software.

Project Chief: Dr. M.G. Skafel
Study Leaders: C.T. Bishop,
Dr. M.A. Donelan, P. Engel

Technical staff:

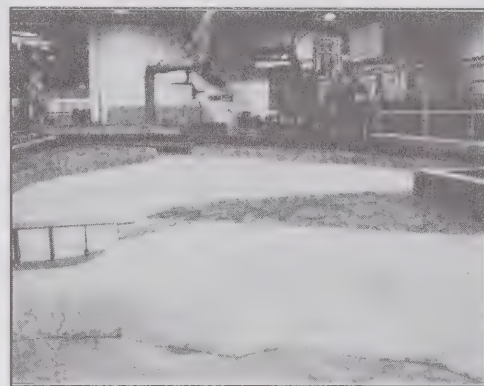
D. Beesley, C. Bil, J. Dalton,
D. Doeden, F. Dunnett, D. Fekyt,
J. Heidt, W. Moody, B. Near,
T. Nudds, R. Stephens, W.B. Taylor,
B. Trapp, G. Voros

Recent publications

Engel, P. and P. Zrymiak. 1989. Development of a calibration strategy for suspended sediment samplers—Phase I. NWRI Contribution 89-121.

Engel, P. and Y.L. Lau. 1989. Laboratory tests of artificial control for Milk River—Phase II. NWRI Contribution 89-92.

Engel, P., Y.L. Lau and M.O. Spitzer. 1989. Effects of bed level fluctuations on discharge measurement in alluvial streams. Proceedings of the Annual Conference and the 9th Hydrotechnical Conference,, Vol. IIB Hydrotechnical, Canadian Society for Civil Engineering, St. John's, Nfld.



Windermere Basin model.

NWRI'S SECOND VOLLENWEIDER LECTURESHIP

The 1989 Vollenweider Lecture in Aquatic Sciences was awarded on November 8, 1989 to Dr. Charles R. Goldman, Professor of Limnology and Chairman of the Division of Environmental Studies, University of California, Davis. Professor Goldman is recognized internationally for his 30 years of ecological research on Lake Tahoe and for his analysis of lakes and impoundments throughout the world. The key to his success has been his ability to combine effective research with responsible social action and policy engagement.

The Vollenweider Lectureship is granted annually to an eminent freshwater scientist for his/her global contribution to the advancement of aquatic sciences. The Lectureship has been established in honour of Dr. Richard A. Vollenweider on the occasion of his retirement from the Public Service of Canada in 1988. Dr. Vollenweider is currently NWRI's Emeritus Senior Scientist designate.

STAFF NEWS

New Fellow of the American Meteorological Society

Dr. M. A. Donelan, Research and Applications Branch, has been elected fellow of the American Meteorological Society in recognition of his outstanding and sustained contributions to atmospheric and oceanic sciences. He has been an active member of the Society since 1981 and chaired its Committee on the Interaction of the Sea and Atmosphere in 1984 and 1985. Dr. Donelan has published many articles on the subject of waves and air-sea interaction, including a chapter (Air-Sea Interaction) for the 9th volume of *The Sea*, a compendium of oceanography.

Visiting Scientists

The Lakes Research Branch was host to several visiting scientists from Europe in the summer and fall of 1989. **Dr. M. Panizutti** of Centro Nazionale delle Ricerche, Milan, worked with **Dr. E. Halfon** for three months on modelling procedures. **Dr. R. Markosova**, associate professor in the Department of Hydrobiology, Charles University, Prague, worked on nutrient-contaminant interactions in Hamilton Harbour for three months with **Dr. J.H. Carey**. **Dr. A. Nauwerk**, Director of the Limnology Institute, Mondsee, Austria, visited NWRI for a week and gave several seminars on species succession of zooplankton and phytoplankton.

Editor's Award

F.M. Boyce, Lakes Research Branch, is the 1989 recipient of the Editor's Award from the International Association of Great Lakes Research. The award recognizes outstanding support of the Association's journal and its peer review process.

■ COMING EVENTS ■

March 14-16, 1990: CLIMATE CHANGE: IMPLICATIONS FOR WATER AND ECOLOGICAL RESOURCES. This international symposium/workshop to be held at the Waterloo Inn, Waterloo, Ontario, is sponsored by the Canadian Climate Centre and the Sustainable Development Branch of Environment Canada, the Canadian Committee on Land Classification and The Water Network (an initiative of the Grand Valley Conservation Foundation). There will be working groups on: water resources, supply and demand; wetlands, wildlife and fisheries; energy and transportation; agriculture and forests; and conservation strategies. Plenary speakers will include Will Kellogg, National Centre for Atmospheric Research, Boulder, Colorado; Bill Riebsame, University of Colorado; Stan Rowe, University of Saskatchewan; Elizabeth Dowdeswell, Atmospheric Environment, Environment Canada; and Jim Bruce, former Assistant Deputy-Secretary General of the World Meteorological Organization. For further details, contact: M. Sanderson, A/Director, The Water Network, c/o Department of Geography, University of Waterloo, Waterloo, Ontario N2L 3G1. Telephone: (519) 885-1211, Ext. 6962; Fax: (519) 746-2031.

June 4-5, 1990: ADVANCED OXIDATION PROCESSES FOR THE TREATMENT OF CONTAMINATED WATER AND AIR, Days Inn, Toronto Airport, Toronto, Ontario. This symposium is sponsored by the Wastewater Technology Centre (Environment Canada), the Canadian Association on Water Pollution Research and Control, and other leading research institutions, industry and government agencies active in the advanced oxidation processes field. Its objectives are: to identify and discuss state-of-the-art and emerging technologies in the advanced oxidation processes (AOP); to examine case studies that have successfully demonstrated, at bench-scale, pilot-scale and full-scale levels, the use of AOP for the removal of organics in water and air; to discuss current and pending R & D studies. Poster sessions will be included in the program. For further information, please contact: WTC AOP Symposium, Marbek Resource Consultants, 2211 Riverside Drive, Suite 407, Ottawa, Ontario K1H 7X5. Phone: (613) 523-0784; Fax: (613) 523-0717.

July 10-12, 1990: NORTHERN HYDROLOGY SYMPOSIUM, Saskatoon, Saskatchewan. This symposium is being held to assist in the planning and development of the Northern Water Systems program, one of the three major research programs of the National Hydrology Research Institute.

The main topics covered will be: snow hydrology, permafrost hydrology, ground-water hydrology, glacier hydrology, hydrology of floating ice, regional water balances, regional energy balances, water quality, and water management. For further information, please write to: Scientific Information Division, National Hydrology Research Institute, 11 Innovation Boulevard, Saskatoon, Saskatchewan S7N 3H5.

August 27-30, 1990: AQUATIC ECOSYSTEMS IN SEMI-ARID REGIONS: IMPLICATIONS FOR RESOURCE MANAGEMENT, Saskatoon, Saskatchewan, sponsored by the National Hydrology Research Institute and The Rawson Academy of Aquatic Science. The objective of the conference is to bring together aquatic scientists, resource experts and managers with an interest in aquatic environments in semi-arid regions to examine existing knowledge of these systems and the options and opportunities for their effective management. For further information, please write: Scientific Liaison & Systems Division, National Hydrology Research Institute, 11 Innovation Boulevard, Saskatoon, Saskatchewan S7N 3H5.

INFORMATION SURVEY RESULTS

We wish to thank our readers who completed the Information Survey inserted in issue 6 of NWRI Digest. Over 200 replies were received, totalling about 12% of our mailing list. Responses came from all sectors: 44% government, 28% university, 18% private sector, and 20% environmental, non-governmental organizations.

We were pleased to discover that NWRI DIGEST is often circulated within an organization and that most of you who replied were satisfied with its format and quality. The majority answered "they *always* read the DIGEST, but were selective in what they read." RESEARCH NEWS (88%) and PROJECT FOCUS (55%) seem to be the sections of particular interest. The five most "wanted" topics were: *fate and pathway of toxic contaminants* (69%), *biomonitoring and ecotoxicology* (52%), *groundwater contamination* (52%), *contaminated sediments* (51%), and *acid and toxic rain* (49%).

Your comments and suggestions were greatly appreciated and will help us improve the newsletter. Several names were also added to our distribution list of approximately 2000.

About NWRI

Environment Canada's National Water Research Institute (NWRI) conducts a national program of original research and development in the aquatic sciences, in partnership with the international freshwater science community. The twin goals of the Institute are to advance scientific understanding of national and international water issues important to Canada, and to develop knowledge and authoritative expertise on these issues that can be used by Environment Canada to influence decisions affecting the wise management of Canada's water resources.

Research at NWRI is conducted within multidisciplinary projects, each focusing on a priority issue. Projects are grouped within three branches: the Lakes Research Branch, the Rivers Research Branch, and the Research and Applications Branch. Current long term research priorities include: toxic chemicals in the Great Lakes and the St. Lawrence River; exchange of toxic contaminants between air, water, sediments and biota; underground contamination; pesticide contamination in rivers; acid rain; lake rehabilitation; aquatic monitoring; ecotoxicology; and risk prediction methodologies.

NWRI Digest

The NWRI Digest is the quarterly public newsletter of the National Water Research Institute, Conservation and Protection, Environment Canada. Suggestions, comments and further enquiries concerning newsletter items are welcomed. Please write to the Editor, NWRI Digest, National Water Research Institute, P.O. Box 5050, Burlington, Ontario, Canada L7R 4A6.

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BEYOND GIS THERE IS ... RAISON

A number of years ago, as part of the acid rain program (LRTAP), NWRI came to the conclusion that "expert systems" offered effective alternatives to traditional scientific methods for the evaluation of surface water quality and for the prediction of aquatic consequences of various policy options for reducing sulphur emissions. That decision led to the development of RAISON (Regional Analysis by Intelligent Systems ON a micro-computer), a software system used for data integration and management, and for data analysis and display.

RAISON utilizes and incorporates a GIS (geographical information system) package with a numerical modelling and expert systems capability specifically designed to deal with surface water management.

INSIDE

- NWRI Participation to GLOBE '90
- NSERC/Industrial Collaborative Project
- Elmira Groundwater Decontamination
- Fraser River Estuary Management Plan
- Impact of Hagersville Tire Fire
- Designing for Floods in Canada
- Importance of Dissolved Organic Carbon in Aquatic Systems
- Remediation of Groundwater Contamination
- Toxicity Assessment and the Importance of Breakdown Products
- Expert Systems to Predict Pesticide Migration and Transport
- Rotating Circular Flume
- Rivers Research Branch Reorganization
- Analysis of Dioxins in Environmental Samples
- WHO Secondment to the Philippines
- Global Sources, Pathways and Sinks of Metals
- Low-Tech Microbiological Water Quality Tests

Requiring only inexpensive micro-computer hardware, RAISON was instrumental in mobilizing and integrating Canadian surface water data and in defining the aquatic consequences of various U.S. and Canadian sulphur emission options. The output of this program contributed to the defense of Canadian interests in LRTAP negotiations with the U.S. government.

The current version of RAISON is designed for a wide range of water management problems. The data assembly capability permits interrogation of diverse data bases and the assembly of data sets according to user-specified criteria. Output of statistical analyses for interactive interpretation of water data can be graphed and tabulated on the screen or colour printer. Together with the GIS component, RAISON is especially useful for visual description of point and spatial data for State of Environment (SOE) reporting and for visualizing alternative water management possibilities arising from modelled relationships. RAISON is, however, significantly different from commercial GIS systems because it is designed specifically for modelling and prediction purposes. Numerical models of expert systems can be either built directly into RAISON or can be appended to the RAISON package.

RAISON is not designed as an off-the-shelf product. It is an application software which users can manipulate via the RAISON programming language (RPL) which was developed for RAISON applications. RAISON is designed to interface with commercial GIS and data base products. RAISON is now widely used in Canada and internationally in a range of situations, from straightfor-

ward statistical and descriptive applications, as in SOE reporting, to complex predictive modelling. Modelling applications are diverse and include disaster (spill) management, modelling of options for mine locations relative to potential aquatic impact of effluent and behaviour of selected priority chemicals in riverine and estuarine situations. An expert system version of RAISON has been applied by the Government of Malaysia for managing rural groundwater wells for domestic water supply. The United Nations Environment Programme (UNEP) has recently contracted NWRI to adapt RAISON for management of the global water component of UNEP's Global Environmental Monitoring System (GEMS/Water).

Because of its potential for improving Canada's capability to assess environmental factors on a regional basis, RAISON was selected by Industry, Science and Technology Canada to receive funding under their Strategic Technologies Program in the area of Artificial Intelligence (AI) research projects in federal departments. One of the advantages of the AI approach is the ability to include in scientific models the non-numeric and judgemental information (i.e., experience) which water managers gain through years of experience.

The RAISON system is described in a brochure available from the RAISON coordinator, Rivers Research Branch.

**Dr. E.D. Ongley, Director
Rivers Research Branch**

**Dr. D.C.L. Lam, Chief
Basin Integration and Modelling
Rivers Research Branch**

RESEARCH NEWS

NWRI Participation to GLOBE '90

From March 19–23, 1990, Vancouver was host to GLOBE '90, the first in a series of biennial "Global Opportunities for Business and the Environment" events. Some 3500 participants from 60 countries attended the week-long international Trade Fair and Conference, which offered a variety of presentations and exhibits addressing the challenges and opportunities arising from the implementation of sustainable development.

As part of Environment Canada's Inland Waters Directorate's participation in the GLOBE '90 Trade Fair, NWRI displayed some of the Institute's capabilities and recent achievements. The two NWRI booths exhibited the following topics: RAISON (Regional Analysis by Intelligent Systems ON a micro-computer), a micro-computer-based, interactive environmental evaluation tool; the use of robotics in analytical chemistry automation;



Environment Minister Lucien Bouchard at IWD's display.

the use of a continuous-flow, large-sample extractor for preparative work in environmental trace analysis; the development of analytical reference materials and certified reference materials for quality assurance/quality control studies; and a reduced scale model of a Par-

shall water flume used in hydraulic modelling studies. By all account, NWRI involvement was very successful in promoting the Institute to the thousands of visitors that attended the trade show. Technology transfer opportunities anticipated to accrue from the event

NSERC/Industrial Collaborative Project

Dr. E. Prepas, University of Alberta, and Dr. T.P. Murphy, Lakes Research Branch and adjunct to the Boreal Institute, University of Alberta, have received a three-year grant from the Natural Sciences and Engineering Research Council (NSERC) to support their research on the use of oxygen injection for lake restoration. Linde Ltd. will provide an equivalent funding towards engineering resources to increase the efficiency of oxygen injection. The funding received from NSERC will support four graduate students working on the biological response of the aquatic biota in Amisk lake, near Edmonton.

Elmira Groundwater Decontamination

Photo-oxidation of dimethyl nitrosamine in groundwater at Elmira, Ontario, will be evaluated in a combined research project utilizing expertise from the private sector, the Wastewater Technology Centre and NWRI. Dr. J.H. Carey's research on ultraviolet oxidation enhancement will be further developed to allow an on-site treatment facility to discharge decontaminated groundwater into surface waters.

Fraser River Estuary Management Plan

Drs. J.H. Carey, P.F. Hamblin and C. Murthy, Lakes Research Branch, participated in the annual Fraser River Estuary Management Plan (FREMP) meeting in Vancouver. Dr. Carey provided a keynote address on organic contaminants in the Fraser River. The implications of his research conclusions on the FREMP monitoring plans were that special monitoring strategies are required to deal with the episodic inputs of contaminants; the sediment wedge phenomenon should be accounted for in monitoring and fate modelling; monitoring and characterization of sources of contaminants from pulp mills in British Columbia must be carried out; and contaminant "fingerprint" scans need to be developed to allow the detection of new and potentially deleterious types of organic chemicals.

Impact of Hagersville Fire

Federal activities related to the potential environmental impact of the tire fire in Hagersville, Ontario, have involved NWRI staff at various levels. While the Water Quality Branch took the lead in monitoring and assessment, extensive field support was provided by NWRI's Research Support Division, with advice and specialized assistance from NWRI's research branches. B.J. Dutka applied his "battery of tests" to rapidly estimate the toxicity of water samples from the

area. The results generated from those tests provide useful and quick information to managers, especially when there is a wide spectrum of organic chemicals resulting from the fire. Based on his field visits and ongoing review of new information, K. Novakowski provided information on the potential for groundwater contamination.

The Rivers Research Branch has continued to provide advice and assistance to federal and provincial authorities on the estimation of existing and potential impacts after the fire has been extinguished. Dr. S. Lesage has provided the

National Water Quality Laboratory with information on the nature of contaminants originating from the fire, many of which are rubber additives. Mr. Dutka has continued his study of the relative toxicity of water samples. The Ontario Ministry of the Environment requested and funded the application of the RAISON expert system to the fire site and downstream affected areas. Aimed principally at data management and impact evaluation, the study provides a good demonstration of RAISON's ability to assist in offering the needed information in an emergency situation.

Designing for Floods in Canada

The concept of a Canadian code of practice for flood design was first proposed in the late 1970s. Following some preliminary work, the Canadian Council of Resource and Environmental Ministers decided to sponsor the development of such a code in 1981. The preparation of the code was under the guidance of an editorial board headed by Professor W.E. Watt, Queen's University, Kingston, and was completed by a team of 21 writers, including J. Marsalek, Rivers Research Branch, and Professor G. Patry, McMaster University, who jointly contributed the chapter on urban design floods. A chapter was devoted to ice jam effects and recommends engineering methods developed at NWRI. The final product has been recently published by the National Research Council of Canada under the title "Hydrology of Floods in Canada: A Guide to Planning and Design." The Guide consolidates technical information related to the analysis of floods in Canada and the determination of "design floods" for projects and studies in public works, water resources and land development. Adoption of the Guide in Canadian engineering practice should result in better flood protection designs and reduced flood damages.

Reference

National Research Council of Canada, Associate Committee on Hydrology. 1989. Hydrology of Floods in Canada: A Guide to Planning and Design, W. Edgar Watt, Editor-in-Chief, 245 p., NRCC No. 29734. (Available from: Publication Sales and Distribution Office, National Research Council of Canada, Ottawa, Ontario K1A 0R6).

Importance of Dissolved Organic Carbon in Aquatic Systems

Composed of a vast variety of compounds, from easily metabolized cellular by-products to persistent humic and fulvic acids, dissolved organic carbon (DOC) plays a particular role in the effects of acid rain in aquatic ecosystems. DOC contributes to both the acidity of water and to its buffering capacity. It has also the tendency to loosely bind aluminum and other metals, therefore decreasing their toxicity. The role and importance of DOC as a modifier of processes and functions has been described in recent publications. In brown waters, DOC was found to be composed of a great variety of components which may differ according to place and time. The information was incorporated into the modelling of the impacts of long range transport of atmospheric pollutants. Other papers describe the stability

of DOC in acidifying waters; the toxicity of aluminum according to the composition; and the effect of different DOC concentrations on the bioaccumulation and acute toxicity of synthetic pyrethroid insecticides to *Daphnia magna*.

References

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- Day, K.E. 1990. Effects of dissolved organic carbon on accumulation and acute toxicity of fenvalerate, deltamethrin and cyhalothrin to *Daphnia magna* (Straus). NWRI Contribution No. 90-50.

Remediation of Groundwater Contamination

A recent report describes the result of years of monitoring and investigation at the Transport Canada "special waste compound" of the Gloucester landfill at Ottawa Airport. The report considers remedial alternatives and recommends a five-year pump-and-treat operation, after which excavation to access non-aqueous phase liquids and/or *in situ* bioremediation may be required. The study emphasizes the fact that groundwater contamination is always cheaper and easier to avert than it is to rectify.

References

- Jackson, R.E., S. Lesage, M.W. Priddle, A.S. Crowe and S. Shikaze. 1989. Contaminant hydrogeology of toxic organic chemicals at a disposal site, Gloucester, Ontario. 2. Remedial investigation. NWRI Contribution No. 89-154.

Toxicity Assessment and the Importance of Breakdown Products

Research in the field of toxic organic chemicals carried out in the Rivers Research Branch emphasizes chemical degradation as well as the nature and effects of the resultant breakdown products. Drs. K.E. Day and R.J. Maguire continue their investigation into the chemistry and toxicity of deltamethrin, a pyrethroid insecticide which is rapidly degraded. In a recent paper, they show that at least one of the isomers, into which the pesticide may be converted in natural water, exhibits an acute toxic effect upon *Daphnia magna*.

Other recent Rivers Research Branch studies have examined the toxicity of chemical mixtures and biodegradation products. Dr. D.L.S. Liu showed that the toxicity patterns of chemical mixtures on biota are extremely complex. Therefore, the approach of setting water quality standards, based on the effect of individual chemicals, requires reexamination. In another study, it was concluded that prior acclimation of the bacterial population is a factor not sufficiently considered in models which attempt to predict toxic impacts. Finally, the scientists recommend that known degradation products be incorporated into bioassay procedures. This would greatly enhance the reliability of estimated toxic impacts.

References

Day, K.E. and R.J. Maguire. 1989. Acute toxicity of isomers of the pyrethroid insecticide deltamethrin and its major degradation products to *Daphnia magna*. *Ecotoxicol. Environ. Chem.* 9: 1297-1300.

Liu, D.L.S. 1989. Assessment of the interaction between microorganisms and chemical mixtures using resazurin reduction. *Toxicity Assessment* 4: 463-471.

Liu, D.L.S. and G. Pacepavicius. 1989. A systematic study of the aerobic and anaerobic biodegradation of 18 chlorophenols and 3 cresols. NWRI Contribution No. 89-76.

Liu, D.L.S., R.J. Maguire, B.J. Dutka and G.J. Pacepavicius. 1989. Rationale for including metabolites in chemical toxicity bioassay. NWRI Contribution No. 89-159.

Expert Systems to Predict Pesticide Migration and Transport

Dr. A. Crowe and J.P. Mutch, Rivers Research Branch, are working on a two-year study to develop an expert system for predicting the migration and transformation of pesticides in soil and shallow groundwater. The study is done in support of the requirement to assess the potential adverse effects of a pesticide and its degradation products on soil and shallow groundwater, before the pesticide is approved for public use. The work is funded by the Pesticide Division of the Commercial Chemicals Branch (Conservation and Protection), which is responsible for the assessments. Three reports give an excellent overview of the usefulness of expert systems applied to similar problems, and provide

a description of the two-year research program. The first phase of the project has been completed and consisted of a review of existing pesticide transport and degradation models which may be suitable for incorporation into the expert system.

References

Crowe, A.S., J.P. Mutch and R.E. Jackson. 1989. An expert system for assessing the migration and transformation of pesticides in the subsurface. NWRI Contribution No. 89-151.

Mutch, J.P. and A.S. Crowe. 1989. Phase one report: a review and analysis of existing pesticide transport and transformation models. NWRI Contribution No. 89-172.

Crowe, A.S. and J.P. Mutch. 1990. Assessing the migration and transformation of pesticides in the subsurface: the role of expert systems. NWRI Contribution No. 90-57.

Rotating Circular Flume

A seven-meter rotating flume has recently been installed in the Hydraulics Laboratory. The new and unique piece of equipment has been designed by NWRI specifically for the study of long-distance transport of fine sediments. Preliminary testing of the flume has started. It will be used by Dr. B.G. Krishnappan, Rivers Research Branch, to study in-stream fine particle processes, such as flocculation and associated transport of contaminants. After testing and calibration, instrumentation, such as a Malvern particle-size analyzer, will be installed in the flume. The availability of this facility was a major factor in attracting Professor Partheniades, University of Florida, a world expert in the field of fluid hydraulics of fine particles, who will be a visiting scholar from September 1990 to March 1991, on his sabbatical leave, and E. Skarbøvik, a doctoral student from the University of Oslo, in residence at NWRI for a nine-month period.

Rivers Research Branch Reorganization

Reflecting altered priorities and scientific approaches, the Rivers Research Branch has reorganized its project structure as of April 1990. The Ecotoxicology and River Contaminants projects have been merged into the new **Ecotoxicology and Environmental Chemistry Project**, headed by Dr. R.J. Maguire. Capabilities in data handling, modelling and forecasting, developed under the

LRTAP program, have been regrouped into a project headed by Dr. D.C.L. Lam and called **Basin Integration and Modelling**. The ongoing study and monitoring of LRTAP effects at the Turkey Lakes Watershed and elsewhere, and the studies of the Athabasca River, Great Lakes tributary loadings and environmental hydraulics form the **Environmental Hydraulics and Large Basin Studies Project** under Dr. S. Lesage. The **Groundwater Contamination Project** remains unchanged.

Analysis of Dioxins in Environmental Samples

The development of improved methods and procedures for the analysis of dioxins in various environmental matrices continues to be the focus of many analytical chemistry research studies. Recent research projects carried out by staff of the Research and Applications Branch have contributed to this field.

Investigations by Dr. J.P. Sherry and collaborators have led to the development of a new and more efficient method for the extraction and clean-up of polychlorinated dibenzo-p-dioxins in fish tissues. The new method incorporates a neutral solid phase extraction procedure in lieu of the conventional, laborious and time consuming liquid phase acidic extraction procedure. This new method also substitutes a multi-layer solid phase clean-up step for the three lengthy and tedious liquid phase clean-up steps commonly used. Comparable recoveries of the analytes of interest have been achieved when the two methods are used with a variety of fish samples spiked at the 10–100 ppt level.

Environmental analytical laboratories are often confronted with very large numbers of samples which are submitted for a particular organic residue analysis, a situation that calls for the development of reliable screening tests capable of detecting the presence of the analyte of interest. With the availability of such screening tests, the full quantitative analytical procedures then need only to be applied to the samples which test positive during screening. The resource-intensive protocols for dioxin analysis constitute a prime area of interest for screening tests, and radioimmunoassay (RIA) techniques have been regarded for some time as promising.

As part of a research project on the development of a RIA screening test for polychlorinated dibenzo p-dioxins, Dr. Sherry has investigated procedures for

the solubilization step of the test and their effect on the performance of the assay at low dioxin levels. Among the various solvents evaluated, dimethyl sulfoxide (DMSO) was found to perform best. A DMSO-based assay was shown to give the best precision and sensitivity by providing a more suitable medium for the solubilization of hydrophobic dioxins and the antibody binding processes taking place during the assay.

At the conclusion of an extensive review of the scientific and technical literature, over the past 10–12 years, on the analysis of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans, Dr. B.K. Afghan has proposed a reference method for the analysis of these parameters in pulp and paper effluents and receiving waters. The proposed method incorporates matrix specific extraction and clean-up procedures and an analytical protocol based on a combination of high resolution capillary column gas chromatography and high resolution mass spectrometry systems. The method has been estimated to have a detection limit of 10 pg/L for 2,3,7,8-tetrachlorodibenzo-p-dioxin in reagent water.

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WHO Secondment to the Philippines

M.N. Charlton, Lakes Research Branch, was seconded for a two-month period to the Regional Centre for the Promotion of Environmental Planning and Applied Studies of the World Health Organization (WHO), in the Philippines. The work was conducted for the Laguna Lake Development Authority at the request of the Philippines government. Laguna Lake is the largest lake in Southwest Asia and is used for irrigation, fish culture, industry, and oil barging. The lake shores and tributary rivers are densely populated and with very few modern sanitary facilities. Within two years, water from the lake will be withdrawn for Manila's drinking water supplies. A monitoring program has been in place for the last 15 years but little use has been made of the data. Mr. Charlton analyzed long-term data sets and showed how these could be used to answer local controversies. Training was also provided in computer techniques and field procedures.



M.N. Charlton lowering an Ekman dredge into L. Laguna.

PROJECT FOCUS

GLOBAL SOURCES, PATHWAYS AND SINKS OF METALS

by Dr. J.O. Nriagu

Air-Water Interactions Project, Lakes Research Branch

Metals have played a key role in the development of human culture and are indispensable to a modern society. However, each metallic compound employed by science and technology generates different types of metallic waste. In addition, the consumption of fossil fuels is responsible for considerable discharge of trace metals. The following discussion focuses on anthropogenic discharges to the atmosphere, the waterways, the oceans and the land. Natural "discharges" which arise from weathering, volcanic eruptions and biogenic emissions are also discussed.

Natural emissions of trace metals in the atmosphere are from three main sources. Wind-wafted soil particles account for over 50% of the Mn, Cr and V, and for 30–50% of the Sb, Ni, Mo and Zn. Volcanoes contribute over 60% of the Cd, 40–50% of the Hg and Ni, and 30–40% of the As, Cr and Cu fluxes from natural sources. Biogenic sources are the leading contributors of As, Hg and Se. In some instances (e.g., soils), it is conceivable that a proportion of the metals emitted is in fact from anthropogenic origin.

Recent crude global inventories of atmospheric metal emissions from all sources leave no doubt as to the great significance of industrial activities on the global cycling of the trace metals. The three main industrial sources of atmospheric metal pollution are (1) mining, smelting and refining of metals; (2) burning of fossil fuels; and (3) the production and use of metallic commercial products. Smelters represent the leading source of As, Cu and Zn, while the manufacture of steel is responsible for the largest fractions of the pollutants Mn and Cr released to the global atmosphere. The burning of fossil fuels to generate energy accounts for over 95% of the pollutant V, and 80% of the pollutant Ni, hence the use of these two elements to identify air parcels derived from power plants. Fossil fuels also account for about 69% of the Hg, Se and Sn and are also a significant contributor of the Sb, As, Cu and Se emitted anthropogenically. In spite of the reduced use of leaded gasoline in many countries, the automobile tailpipe still accounts for nearly two-thirds of the lead emission. A large fraction of the airborne As is still being derived from the spray of arsenical insecticides.

At present, industrial emissions dominate natural fluxes. On a global scale, anthropogenic emissions of Pb, Cd, V and Zn exceed the fluxes from natural sources by 28-, 6-, and 3-fold, respectively. Industrial contributions of As, Cu, Hg, Ni and Sb exceed those by natural sources by 100–200%. In urban areas and around some point sources, however, industrial fluxes would be even greater.

The atmosphere has become a key medium in the transfer of trace metals to remote aquatic ecosystems. On a global scale, this pathway annually supplies over 70% of the Pb, 40% of the V, and 20% of the Hg and Cd flux into aquatic ecosystems; the inputs of other trace elements from this source average about 10%. However, in many rural and remote regions, the atmosphere supplies most of the trace metal entering aquatic ecosystems. For example, well over 50% of all the trace metals getting into the Great Lakes is via the atmosphere (Nriagu, 1986).

An extensive survey of the global distribution of lead in the marine atmosphere (Volkening et al., 1988) found the highest concentrations near the urban/industrial areas off Western Europe and eastern North America, and the lowest levels in Antarctica. A previous study by Boutron and Patterson (1987) had reported a 4-fold increase in the lead concentration in the Antarctic ice layers. In late spring of each year, the Arctic region is covered by a haze containing elevated levels of trace metals derived from industrial sources in Eurasia (Shaw and Khalil, 1989; Maenhaut et al., 1989). The Arctic haze affects nearly 9% of the earth's surface area and is the most extensive air pollution system known. The available evidence thus points to the fact that few places on earth are free of trace metal pollution.

While it is well known that domestic and industrial wastewaters, sewer discharges and urban runoff contribute to the aquatic environment often in large, concentrated amounts, it is less well known that disposal on land is also significant. The disposal of fossil fuel residues and the general wastage of commercial products on land account for about 55–80% of the metal pollution in soils. The large volumes of wastes associated with animal husbandry, logging, agriculture and

food production often affect the trace metal budgets of many soils. Agricultural soils accumulate metals from the atmosphere, fertilizers, pesticides and manure. For example, it has been estimated that the average Cd input into agricultural lands in Europe is about 8 g/ha/y from the atmosphere and 5 g/ha/y from phosphate fertilizers (Hutton, 1982). In Belgium, metal contamination of agricultural soils from fertilizers and the atmosphere has been estimated to average 16, 20, 260 and 3800 g/ha/y for As, Cd, Pb and Zn, respectively (Navarre et al., 1980). At such loading rates, there is a growing concern that large areas of arable soils in Europe may be close to exceeding their carrying capacity for trace metal pollution. In Japan, on the other hand, the problem has become real—about 9.5% of the paddy soils, 7.5% of the orchard soils and 3.2% of the upland soils in this country have been rendered unsuitable for growing rice for human consumption because of excessive metal contamination (Asami, 1983).

The comparison between the anthropogenic mobilization of trace metals and the weathering cycle flux indicates the dominating influence of industrial discharges on the trace metal budget of the biosphere, with the possible exception of Mn and V. For Sb, Cu, Pb and Zn, the industrial discharges exceed the weathering flux by about 3-fold; for Hg it is 10-fold. When the mine outputs of the metals are also taken into account, there can be no doubt that mankind has become the key agent in the global mobilization of trace metals into the biosphere. Most of the industrial discharges occur in the Northern Hemisphere, and their effects on the trace metal cycles in this region should be profound.

Trace metals in the soils in urban areas and around major industries (Adriano, 1986; Purves, 1985) are quite elevated. The median values and typical ranges (in brackets) of values reported for atmospheric fallout of trace metals in the urban areas of North America are 160 (20–980) g/ha/y for Cu; 910 (140–3500) for Pb; 18 (7–36) for Cd; and 3200 (80–4800) g/ha/y for Zn (Jeffries and Snyder, 1981). At these deposition rates, the levels of most of the trace metals in soils should be doubled in 2–10 years, depending on the baseline metal contents.

historically, the developed countries have been responsible for most of the usage and discharge of metals. Current development trends, however, suggest sharp increases in the release of these metals by the developing countries in the near future. For example, the high rate of population growth may result in a larger demand for metallic goods as economic conditions improve. Most of the population growth is concentrated in urban areas which have traditionally been "hot spots" of metal pollution. Thus, the combination of high population growth, rapid economic development and the lack of government regulations may lead to an increase in the rate of metal emissions in some developing countries. Whether these increases will be matched by greater decrease in the developed countries remains to be seen.

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LOW-TECH MICROBIOLOGICAL WATER QUALITY TESTS

In developing countries throughout the world and in isolated communities in North America, a need to ensure that drinking water supplies are adequate, safe and accessible is always present. Attempting to optimize these three attributes is not easy at the best of times, but is exceedingly difficult when resources are scarce and technology or expertise is not readily available.

In attempting to reach a local balance between these three objectives, a major consideration is the establishment of realistic quality standards combined with an ability to monitor for compliance with those standards and to respond to cases of non-compliance. One such quality standard which is fairly fundamental is that drinking water quality should be free from the influence of human or animal faeces with its attendant risk of water-borne diseases. The traditional assessment of water status in reference to this objective has been the testing for the presence of coliform bacteria, particularly faecal coliforms and *Escherichia coli*, the assumption being that no pathogens will persist any longer than these bacteria once exposed to oxygenated waters. Similarly, it is assumed that no such pathogens will survive that degree of water treatment, such as chlorination, which will render the water coliform free. Studies of disease incidence have tended to support these assumptions and contributed to the establishment of standardized methods for coliform testing in drinking water as a fundamental indicator of quality. However, problems with the use of such established methods in developing countries and isolated areas arise due to a number of factors related to their lack of portability, simplicity and economy; they require trained technicians, sophisticated laboratory equipment and expensive supplies, most of which

are not readily available in such areas. Further, the long incubation times required for some tests hinder the effectiveness of water quality control programs in such areas, since these programs tend to be based on the monitoring of supplies which will be immediately used and whose quality may vary greatly over short periods of time, as opposed to the ongoing monitoring of an industrialized treatment process whose output quality will hardly vary.

To overcome these problems, simplified, inexpensive and reliable microbiological water quality tests are required. Additional design factors for consideration are that such tests should produce rapid results with minimal investment in supplies and equipment.

For the past six years, B.J. Dutka, Rivers Research Branch (RRB) has been involved in an nine-country, three-continent study, funded by the International Development Research Centre (IDRC), on the development and use of such tests. Researchers in Brazil, Chile, Egypt, Malaysia, Morocco, Peru, Singapore and Thailand have examined a number of promising, non-traditional microbiological tests and have adapted them to their particular conditions and needs. As described in a recent IDRC publication, edited by RRB scientists B.J. Dutka and Dr. A.H. El-Shaarawi, the project developed, evaluated and demonstrated the utility of four such tests: the coliphage test, the A-1 broth (MPN) test, and the presence/absence (P/A) and H₂S paper-strip potable water tests.

The five-tube Most Probable Number (MPN) test using A-1 broth was found to be far superior to locally used faecal coliform estimation procedures, since it is simple to perform, relatively inexpensive and more sensitive. Its main drawback for worldwide use is the neces-

sity for incubation at 44.5°C, a temperature not easily achieved in developing countries and isolated rural areas.

The coliphage test is also inexpensive and easy to perform. It tests for the presence of viruses which invade coliform bacteria and has the added advantage of directly suggesting whether water treatment and disinfection have been sufficient to remove possible virological hazards. It also has the advantage of generating results within six hours, allowing a responsive water management program.

Laboratories on three continents studying potable water found that it was not uncommon to find coliform-free water containing coliphage, suggesting that enteroviruses can also survive the normal water treatment processes. In joint studies with the Ontario Ministry of the Environment, B.J. Dutka found that this was also true for treated drinking water derived from both ground and surface water sources in Southern Ontario. These results indicate a need for further work, not only on how common this situation is, but also on the exact relationship between coliphage and pathogen survival in water treatment processes.

In many areas, the coliphage and the A-1 broth tests proved insufficient. Persistent cost problems and the lack of trained personnel allowed the regular consumption of unsafe water. Two other extremely simple, inexpensive and reliable procedures were also proposed and evaluated. Both the P/A and H₂S paper-strip tests are single-bottle tests to which potable water is added and then incubated at between 25 and 35°C for up to five days. The P/A test was found to be the most sensitive and cost-effective test. The media can be transported anywhere and does not require refrigeration; samples can be collected, tested and interpreted by untrained personnel.

The H₂S test is superior in that its medium (an impregnated paper strip) has an unlimited shelf life, but it is based on the testing of a smaller sample than the P/A test and it is therefore less sensitive. Some research into media concentration versus sample volume should allow it to achieve an equivalent sensitivity.

These tests are now being used under a variety of conditions around the world, and requests for information, training or assistance in establishing a local monitoring program are being received regularly. It remains a question of passing the information to those who need it most, with the simple message that any group, anywhere, can now set up a program to ensure the quality of its local drinking water.

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COMING EVENT

August 20-22, 1991: AQUATIC BIRDS IN THE TROPHIC WEB OF LAKES, Mount Allison University, Sackville, New Brunswick. This symposium will focus on the role of aquatic birds in inland water bodies, and especially on the relationship between aquatic birds and nutrient levels, water quality, and aquatic habitats. Proceedings of the symposium will be published in a special issue of *Hydrobiologia*. For further information, please contact: Dr. J.J. Kerekes, Canadian Wildlife Service, Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia B2Y 4A2. Telephone: (902) 426-6356; Fax: (902) 426-7827.

Combined issue this time . . .

The current Digest is a combined issue for the spring and summer of 1990. The regular quarterly schedule will resume with the Fall 1990 issue.



Location of sites in the IDRC-funded study on the validation of simple and inexpensive microbiological tests for the assessment of drinking water supplies.

About NWRI

Environment Canada's National Water Research Institute (NWRI) conducts a national program of original research and development in the aquatic sciences, in partnership with the international freshwater science community. The twin goals of the Institute are to advance scientific understanding of national and international water issues important to Canada, and to develop knowledge and authoritative expertise on these issues that can be used by Environment Canada to influence decisions affecting the wise management of Canada's water resources.

Research at NWRI is conducted within multidisciplinary projects, each focusing on a priority issue. Projects are grouped within three branches: the Lakes Research Branch, the Rivers Research Branch, and the Research and Applications Branch. Current long term research priorities include: toxic chemicals in the Great Lakes and the St. Lawrence River; exchange of toxic contaminants between air, water, sediments and biota; underground contamination; pesticide contamination in rivers; acid rain; lake rehabilitation; aquatic monitoring; ecotoxicology; and risk prediction methodologies.



NWRI Digest

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Digest

SPRING 1991



VIEWPOINT: An Era of Surprises

Looking back at some of the environmental disasters of the past few years (Chernobyl, toxic mussels in Atlantic Canada, the Exxon Valdez spill, and most recently the Persian Gulf oil spills) and the lingering potential threats (stratospheric ozone depletion, desertification, climate change), one must wonder: What on earth is going on? What are we doing to ourselves?

All of these events differ from the past "local" calamities we are familiar with, such as massive fish die-offs and water taste and odour problems. Their scope can be regional, continental or even global and they are exclusively man-made problems. We are beginning to feel the effects of violating the basic laws of nature. Integrity of the biosphere has been disrupted and its built-in resilience is no longer able to buffer the adverse effects of perturbations caused by exploitive human activities.

HIGHLIGHTS

- When is a particle not a particle?
- Hairy algae
- "LEAF" aids in trace metal analysis
- Vollenweider Lectureship in Aquatic Sciences
- Calibration lab accredited
- GLURF encourages research partnerships
- Improving water quality in prairie dugouts
- Scientists study tailings spill
- Coping with zebra mussels

We are beginning to feel the effects of violating the basic laws of nature

We are entering a new phase governed by non-equilibrium thermodynamics and the laws of randomness and chaos from a harmonic steady-state ecological system that we were wrongly taking for granted. From fairly predictable and relatively stable situations, where straightforward solutions (load reduction, zero discharge of contaminants) are possible, our living environment appears to be entering a permanent state of flux and surprises, and we have little or no time to prepare a response.

What is ecological integrity? This term has appeared over the past decade in a number of policy documents related to human activities within the biosphere. The directive of the 1978 Great Lakes Water Quality Agreement between Canada and the U.S. is to "restore and maintain the integrity of the Great Lakes basin ecosystem", but the document does not define the concept of integrity. It can be interpreted in different ways — from impairment of beneficial uses, as applied to the International Joint Commission Areas of Concern, to the concept of "wholeness" of a system and an ability to maintain its organization (i.e. structure and function), in the face of changing conditions and perturbations.

The Literature lists a number of analogous

conceptual terms, such as resiliency, elasticity, vulnerability and stability. The ultimate stage of instability is an ecological collapse. Surprises or unforeseen events are a consequence of disequilibrium caused by violent perturbations and can be expected, but not predicted.

In my own research on unstable hypertrophic lakes in Western Canada, I defined instability by the amplitude of biomass oscillations prior to an ecosystem collapse, which resulted in massive die-offs of the planktonic and fish communities in the lakes. Catastrophe theories and non-equilibrium thermodynamics provide additional quantitative ways to estimate the potentially catastrophic instability of an ecosystem and identify or predict the situation when ecosystem integrity is destroyed.

How can NWRI approach this era of uncertainty? Are we going to be able to predict unforeseen events and future surprises? Should we just wait and see what happens next?

The ultimate stage of instability is an ecological collapse

While we cannot predict the unpredictable, we have to continue the development of models which focus on defining the conditions leading to catastrophic events and estimating their probability. We must anticipate an ever increasing frequency of crisis situations and prepare highly flexible



research strategies in order to address them.

Even if the research gets a substantial increase in its resource base, it is unlikely that we shall be able to provide the needed advice to the government by ourselves. Yet, to be able to cope with the future surprises, we will have to:

- diversify our expertise to include more ecological, engineering and social disciplines and create flexible research teams;
- take the initiative in creating a national and international network of experts to anticipate trouble spots and to form joint projects with other research and development organizations.

NWRI has established good international research collaborations over the past two decades. We should capitalize on this achievement and make more use of our networks to learn from the experience of other countries.

Dr. Jan Barica
Senior Research Scientist
Lakes Research Branch

RESEARCH NEWS

SCIENTISTS STUDY TAILINGS SPILL

The collapse of an abandoned mine tailings pond served as a starting point for Environment Canada scientists studying the impact of tailings spills on aquatic ecosystems.

When a beaver dam upstream of the Matachewan gold mine fell apart, the extra water surged against the containment wall of the mine tailings pond. On October 17, 1990, the wall collapsed under the added pressure and about 300,000 tons of tailings were flushed into Ontario's Montreal River system. At the request of the Ontario Ministry of Natural Resources and the federal Environmental Protection Service, NWRI scientists quickly designed and initiated a study to analyze contaminant levels in mine tailings and bottom sediments.

Alena Mudroch and Dr. Tom Murphy, Lakes Research Branch, collected and analyzed tailing samples as well as sediment cores from the Montreal River system downstream from the spill. Mudroch recorded considerably elevated levels of lead, zinc and copper

in all tailings samples. In some cases the concentrations of these metals were over ten times greater than those observed in nearby lakes.

The contaminants were especially concentrated in smaller particles. Since fine particles are easily carried downstream by the current, this could have a pronounced effect on the river system in the future. At the time of the study, however, the concentrations of lead, zinc and copper in downstream sediment cores were still at natural levels. The information derived from this investigation will serve as a baseline for further assessment of the long-term impact of the tailings release on the Montreal River's ecosystem.

The incident at the Matachewan mine is not an isolated event. Similar spills have occurred over the past ten years and it stands to reason that many of the hundreds of abandoned tailings ponds scattered throughout Canada pose a potential environmental threat.

Contact:
Alena Mudroch, Lakes Research Branch

Determination of non-chlorinated dioxin and furan in defoamers

Staff of the Research and Applications Branch have investigated the quality assurance and analytical chemistry aspects associated with a method of determining low levels of non-chlorinated dioxin and furan.

These compounds contaminate products used as defoamers in pulp and paper mill operations. The use of such defoamers in mills using a chlorine bleaching process can cause a significant increase in the levels of tetrachlorinated dioxins (TCDD) and furans (TCDF) in the final bleached pulp.

As part of control measures to reduce the TCDD and TCDF levels in pulp mill effluents, an analytical method was required for the determination of non-chlorinated dioxin and furan in defoamers. In collaboration with scientists of the Pulp and Paper Research Institute (PAPRICAN), Pointe-Claire, Quebec, NWRI scientists have adapted a method previously developed at PAPRICAN to make it suitable for use as a reference method for the determination of the non-chlorinated dioxin and furan compounds in defoamers, within a detection limit of 1 ng/g.

Reference

Luthe, C.E., Voss, R.H., Lee, H.B., and T.E. Peart. 1990. A proposed method for the determination of dibenzofuran and dibenzo-p-dioxin in defoamers. NWRI Contribution 90-130.

When is a particle not a particle?

To understand how contaminants disperse in water, aquatic scientists must know whether the contaminant is particulate or dissolved. Large particles are easily identified by screening with 450 nm filters, but smaller particles are usually dismissed as solutes because they slip through the filter pores.

More sensitive sampling and characterization techniques are usually too expensive and time consuming for widespread use. But Dr. Gary Leppard, Lakes Research Branch, has developed particle analysis procedures for use in conjunction with transmission electron microscopy (TEM) that make the process cheaper and faster.

The advantage of TEM lies in its ability to resolve particles between 1 to 1000 nm in size. At the lower end of this range lie

many interesting particles such as fibrils, iron colloids and viruses; structures that could be dismissed as solutes when ordinary sampling techniques are used. TEM also allows scientists to examine the shape of a particle and analyze its elemental composition using energy-dispersive spectroscopy.

Dr. Leppard has adapted techniques used in the biomedical sciences for use with TEM and minute particles. A multi-method approach uses techniques from chemistry, microscopy and physics to verify results. The procedures are also designed to minimize degeneration of the sample from its natural state. Taken together, these techniques allow one to systematically identify, assess and reduce false information introduced by the usual methods of separating particles from water. Using TEM is still

expensive, but when refined measurements are essential it is an attractive solution. This technical advance promises to strongly influence the approach taken to investigate all interactions between dissolved, colloidal and particulate matter in natural waters.

Dr. Leppard's research in this area has been funded by diverse agencies such as the National Science Foundation of Switzerland, Environment Canada, the Department of Fisheries and Oceans and several Canadian universities including Toronto, McMaster, Guelph and Quebec.

Reference

Leppard, G.G., Burnison, B.K., and J. Buffle. 1990. Transmission electron microscopy of the natural organic matter of surface waters. *Analytica Chimica Acta* 232: 107-121.

Hairy Algae

Freshwater algae have been found to produce great quantities of little "hairs" or fibrils over their outer cell walls. They were first described in lake waters by Drs. Gary Leppard, Andrew Masalski and David Lean at NWRI more than ten years ago.

The fibrils, which require a transmission electron microscope for detection, are so tiny that a cubic centimetre can contain 40 million kilometres of them. The long sticky hairs are used to bind algal cells together to form colonies and/or anchor them to rocks. They also stick to clay and bacterial particles in the water and are thought to play a role in decontaminating lakes.

The study of their role in algal metabolism and biogeochemical cycles has until recently been hampered by difficulties in obtaining sufficient quantities of fibrils of uniform type that are uncontaminated by detritus and microbial cells. This problem has just been solved in a collaborative study involving Drs. D. Kushner and T. Strycek, Department of Microbiology at the University of Toronto, and Dr. Leppard, Lakes Research Branch.

Drs. Kushner, Strycek and Leppard have assessed the ability of 28 different algal species from the University of Toronto Culture Collection to produce fibrils and have discovered a few species which could be termed "fibril factories". These species are commonly found in lakes of southern Ontario and include *Micrasterias radiata*, *Eremosphaera viridis*, *Microcystis aeruginosa* and *Xanthidium* sp. The combined NWRI/University of Toronto team found that certain algae switch on fibril production when denied nutrients or when the population ages. Environment Canada and the Department of Supply and Services

supported the research.

Future research will focus on the effect of inducing fibril production on pesticide fate in "limnocorrals" in experimental lakes and on the biochemistry of the fibrils themselves. Biotechnology possibilities exist for customizing fibril/contaminant interactions.

Reference

Strycek, T., Acreman, J., Kerry, A., Leppard, G.G., Nermut, M.V., and D.J. Kushner. Extracellular fibril production by freshwater algal species. Submitted to *Microbial Ecology*.

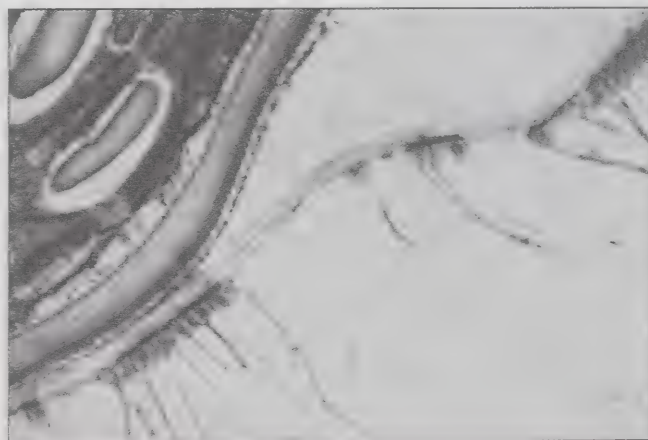


photo by Dr. Gary Leppard

HAIR LOSS: An algal cell, seen here through a transmission electron microscope, sheds an outer layer of cell wall bearing fibrils. The fibrils are produced when nutrients are low and lost during periods of rapid growth.

Vollenweider Lectureship in Aquatic Sciences



Dr. Desmond E. Walling (right), seen here with Dr. Richard Vollenweider, received the 1990 NWRI Vollenweider Lectureship in Aquatic Sciences.

Dr. Desmond E. Walling, Department of Geography, University of Exeter, UK, was the recipient of the 1990 NWRI Vollenweider Lectureship in Aquatic Sciences. The title of Dr. Walling's lecture was "The Wearing Away of the Land: Global and Local Perspectives." Dr. Walling is recognized internationally for his work on land erosion, suspended sediment transport and watershed sediment yields, and he has been actively involved in several UNESCO International Hydrological Programme projects. He is also the editor of the *Journal of Hydrological Processes*.

The Vollenweider Lectureship is granted annually to an eminent freshwater scientist for his or her global contribution to the advancement of the aquatic sciences. It was established in honour of Dr. Richard A. Vollenweider on the occasion of his retirement from the Public Service of Canada in 1988. Dr. Vollenweider is currently emeritus senior scientist at NWRI.

While at the Centre, recipients of the Vollenweider Lectureship assist in the

assessment of NWRI programs and research directions by taking time to review and discuss projects in their areas of expertise. Professor Walling took on this task with a great degree of enthusiasm, holding extensive discussions concerning the fine particle and non-point source pollution programs. His comments have reinforced our conviction that interdisciplinary approaches are the most effective.

Dr. Walling also participated in the 1990 Canadian Hydrology Symposium sponsored for NRC's Associate Committee on Hydrology by Environment Canada, the Ontario ministries of Natural Resources and Environment, and the Canadian Association on Water Pollution Research and Control. The symposium, entitled "Fluvial Sediments: Source, Transfer, Fate and Effects", brought together scientists, engineers and managers from governments, universities and the private sector to discuss the wide-ranging roles fluvial sediments play in engineering, resource management and environmental processes.

Calibration lab accredited

The NWRI Calibration Laboratory recently became the first government laboratory accredited by the Standards Council of Canada to perform certified calibrations of physical and electrical instruments.

The calibrations are traceable to national and international standards under the Canadian Calibration Network (CCN), an agency created to relieve the National Research Council of calibration work which could be performed by other certified laboratories. Under CCN, the NWRI laboratory is authorized to verify the accuracy of instruments measuring electricity, humidity, temperature and pressure.

As was the case with the establishment of certified analytical standards and the interlaboratory Analytical Quality Assurance Program, this initiative was first begun in order to serve the particular needs of the Inland Waters Directorate but is also available to other organizations on a limited basis.

Contact:

Les Peer, Research Support Division

GLURF

encourages research partnerships

The newly created Great Lakes University Research Fund (GLURF) recently awarded 19 grants to universities as part of Canada's Great Lakes Action Plan. The university response to the new fund was enthusiastic and yielded a wide range of projects which covered issues ranging from the fate of toxic chemicals to socio-economic concerns.

GLURF is a subvention program established by Environment Canada in conjunction with the Natural Sciences and Engineering Council (NSERC) to encourage multidisciplinary research, to develop research partnerships among the universities, government agencies and the private sector, and to promote the training and development of new scientists. The fund will grant up to \$1 million per year for four years, beginning in 1990/1991. This

year, two-thirds of the fund was provided by Environment Canada and the remainder was contributed by NSERC.

Over 60 proposals from universities across Canada were received. The applications underwent peer review and final selection was made in late February by the National Evaluation Committee (NEC). The evaluation committee was chaired by Dr. Ralph Daley, Executive Director of NWRI, and made up of equal representation from Environment Canada and universities.

Research priorities for the next year of the program will be available in the near future. The application deadline will be in mid-October for the grants to be awarded in 1992.

Contact:
Science Liaison Division, NWRI

GLURF recipients

The following applicants received GLURF funding for 1990/1991:

W.T. Dickinson, University of Guelph
H.C. Duthie, University of Waterloo
G.D. Haffner, University of Windsor
K.W.F. Howard, University of Toronto
R. Knowles, McGill University
J. Kramer, McMaster University
J. Lovett-Doust, University of Windsor
D. Mackay, University of Toronto
G.L. Mackie, University of Guelph
B.E. McCarry, McMaster University
D.J. McQueen, York University
C.D. Metcalfe, Trent University
R. Peters, McGill University
J.M. Rosenfeld, McMaster University
H.P. Schwarcz, McMaster University
V. Sniekus, University of Waterloo
M.H. Sproule-Jones, McMaster University
W.G. Sprules, University of Toronto
T.H. Whillans, Trent University

COPING WITH ZEBRA MUSSELS



photo by Fernando Rosa

TINY TERROR: Zebra mussels completely cover the bottom of this dissolved oxygen probe retrieved from Lake Erie.

The zebra mussel (*Dreissena polymorpha*) is quickly becoming one of the Great Lake's biggest environmental and economic nightmares, and scientists at NWRI are among those plagued by this molluscan menace.

Colonies of zebra mussels can disable sensitive recording instruments, posing serious problems for in-lake environmental sensing. They also attach to the hulls of research vessels, slowing their progress and causing more money to be spent on fuel and less on science. Finding simple answers to these difficulties is one of the challenges facing the Great Lakes research community.

"LEAF" aids in trace metal analysis

The determination of very low levels of trace metals in environmental samples continues to be a challenge for analytical chemists. High sensitivity methods are needed as too often results of trace metals analyses with existing techniques cannot be quantified beyond "less than" or "non-detectable" statements. A newly developed spectrophotometer promises to greatly enhance the sensitivity of trace metal analysis in environmental samples.

Scientists from the Analytical Chemistry Project, in collaboration with the Ontario Laser and Lightwave Research Centre of the University of Toronto, have successfully carried out a feasibility study on the construction of a laser-excited atomic fluorescence (LEAF) spectrophotometer.

The team has built what is believed to be the first working LEAF spectrophotometer in Canada. A preliminary evaluation of the instrument has produced very promising results, with indications of detection at the sub-parts per trillion level being readily achievable in environmental samples. This new technology is expected to provide a novel and highly sensitive approach for trace metal analysis in environmental samples.

The study team is continuing work in this area, with plans to have a working prototype of the spectrophotometer in the near future.

Reference

Cheam, V., Sekerka, I., and R. Desrosiers. 1990. Laser-excited atomic fluorescence spectrophotometry: a feasibility study on constructing a spectrophotometer. NWRI Contribution 90-128.

Improving water quality in prairie dugouts

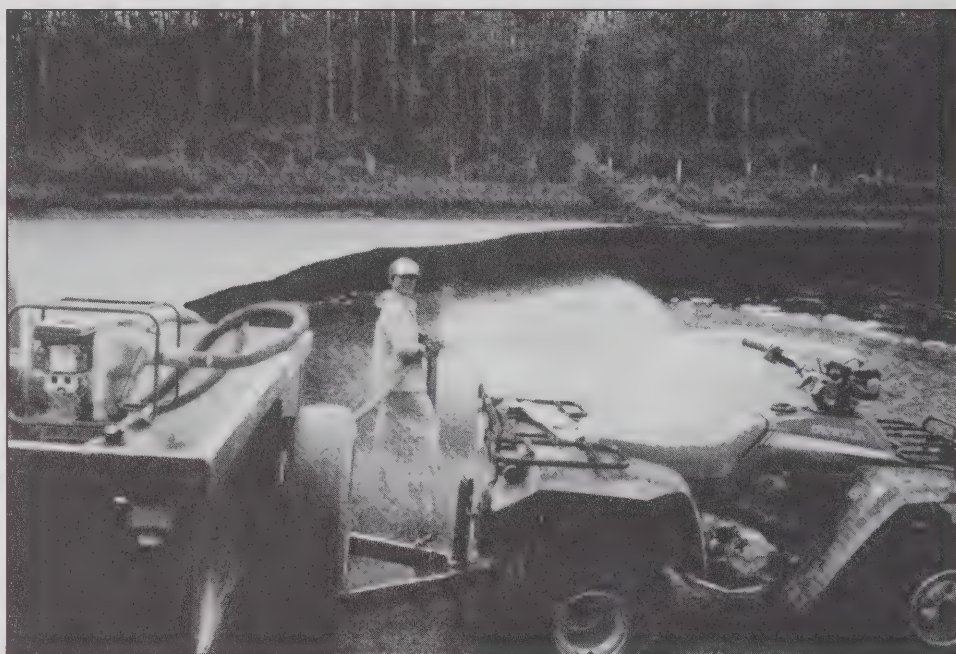


photo provided by Dr. Tom Murphy

A SQUIRT OF LIME: A graduate student from the University of Alberta uses a newly developed slurry maker to spray lime on a dugout congested with algae.

Thousands of farmers throughout the Canadian prairies rely on dugouts for their domestic and agricultural water supplies. But a constant battle is waged in these stagnant ponds against algal growth which clogs filters, causes taste and odour problems and can kill livestock. Copper sulfate is commonly used to kill the algae but the treatment must be repeated every few weeks, leaves a residual taste and is toxic to sheep. A collaborative research project between Dr. Tom Murphy of the Lakes Research Branch and the University of Alberta indicates that lime is a preferable alternative to copper sulfate.

In a study using four hardwater dugouts in northwestern Alberta, lime precipitated over 90 per cent of the algae and the treated dugouts remained clear for two years. Farmers reported that the taste of the water also improved. In addition to this, lime has a very low toxicity compared to copper sulfate, making it a safer water supply for livestock.

Historically, lime was used to combat algae, but the procedure for applying it was so inefficient that applying a much smaller amount of copper sulfate was preferred. But a newly developed slurry maker makes lime application easier and more effective. Dr. Murphy and his co-workers also developed procedures for applying lime without professional help which are now being used by many farmers. Both the slurry maker and the procedures are outlined in a recently produced manual. The study was funded by the Department of Supply and Services, Environment Canada and the Alberta Ministry of Agriculture.

Reference

Prepas, E.E., Murphy, T.P., Babin, J.M. and J.T. Lim. *Farm Water Dugouts: A Manual on the Use of Lime to Provide Good Water Quality*, NWRI Contribution 90-16.



SWADE completes field phase

The field work portion of the Surface Wave Dynamics Experiment (SWADE), an international study involving the participation of NWRI scientists, was completed off the Atlantic coast in Virginia, U.S. The experimental period extended from Oct. 1, 1990 to March 31, 1991. The information gathered in this experiment will contribute toward a better understanding of fundamental physical processes occurring at the ocean-atmosphere interface.

After completing some of this work last fall, the team of scientists and support initiated the most concentrated portion of this field work in January 1991. Different sets of parameters were recorded during the experiments through an elaborate data capture network comprising buoys of various types deployed in the experimental area as well as several airborne systems.

Dr. Mark Donelan of the Hydraulics Project served as the chief scientist in this study. The main source of funding has come from the U.S. Office of Naval Research, the U.S. National Aeronautics and Space Administration (NASA) and Environment Canada.

CANADIAN lake status reviewed

NWRI contributed two "State of the Lakes" reports to the fourth biennial conference on "The conservation and management of lakes", held in China. The conference was organized by the Chinese Research Academy of Environmental Sciences and the International Lake Environmental Committee (ILEC).

Dr. Rod Allan, director, Lakes Research Branch, provided an overview of contaminant trends in the Great Lakes. He noted that concentrations of metals and persistent organochlorine compounds in both sediments and water have been declining for at least ten years. Dr. Allan concluded this was the result of point source pollution controls and that a further decline will be realized

when controls on non-point sources, like those from urban areas and the atmosphere, are devised and implemented.

Colin Gray, Lakes Research Branch, summarized limnological characteristics of 42 lakes in seven Canadian lake regions. The limnology of pristine lakes and those affected by eutrophication, acidification, contamination and/or siltation were compared in each region.

The Canadian lake survey was based on an ILEC questionnaire and undertaken in collaboration with Brock University. It highlighted a significant portion of the limnological research and monitoring undertaken by government agencies and universities over the last 20 years.

References

Allan, R.J. 1991. Toxic contaminants in waters and sediments of the Great Lakes. NWRI Contribution 91-19.

Gray, C.B., Dickman, M., Krushelnicki, B. and V. Cromie. 1991. A survey of Canadian Lakes. NWRI Contribution 91-18.

RAISON adapted for global water programme

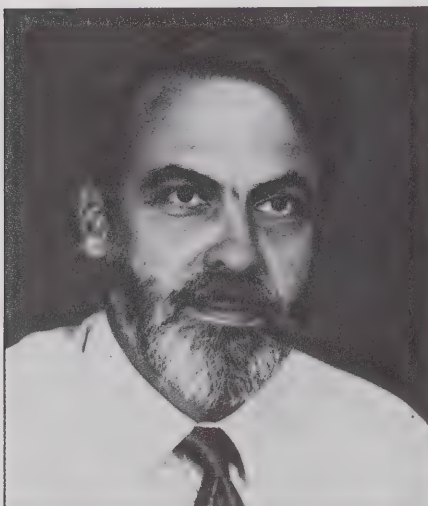
RAISON (Regional Analysis by Intelligent Systems ON a microcomputer) is now adapted for use in a global water quality monitoring programme (GEMS/WATER). The RAISON software, designed at NWRI for water resources management, is used for data

integration, management, analysis, modelling, and display. The RAISON/GEMS package produces summaries, statistical interpretation and synthesis of the extensive GEMS/WATER data holdings.

Andy Fraser implemented the RAISON/GEMS software at the headquarters of the United Nations Environment Programme in Nairobi, Kenya, and the World Health Organization in Geneva, Switzerland.



Staff News



Dr. Ralph Daley assumes his new position as executive director of NWRI.

Dr. Ralph Daley was appointed Executive Director of NWRI, replacing David Egar in Aug. 1990. Dr. Daley has been with the Department of the Environment since 1974 when he began research with NWRI's Pacific and Yukon Detachment on algal and bacterial limnology in the fjord lakes of British Columbia. He was chief of the Science Liaison Division at NWRI before his appointment. His first concern in his new position will be preparing the institute for its role in the Green Plan.

Dr. Michael Zarull has joined NWRI as the Great Lakes officer responsible for the co-ordination of NWRI's research funded by the Great Lakes Action Plan. Mike comes to NWRI from the Great Lakes Office of the International Joint Commission and has a special interest in contaminated sediment remediation.

Dr. Togwell Jackson recently became a member of the Sediment-Water Interactions Project, Lakes Research Branch. He gained recognition for his work on the biogeochemistry of mercury during the English-Wabigoon River pollution studies of the 1970s. Before joining NWRI, he conducted research at the National Hydrology Research Institute in Saskatoon.

Dr. Richard Thomas, senior scientist, Rivers Research Branch, has retired from NWRI after a long career with Environment Canada, Fisheries and Oceans, and the International Joint Commission. He remains active in the scientific community as director of the Great Lakes Institute at the University of Windsor and as an emeritus scientist to NWRI.

ABOUT NWRI

Environment Canada's National Water Research Institute conducts a national program of research and development in the aquatic sciences, in partnership with the national and international freshwater science community. The twin goals of the Institute are to advance scientific understanding of aquatic ecosystems, and to develop authoritative expertise for Environment Canada to develop and implement policies promoting the wise management of water resources in Canada and in other countries.

Research at NWRI is conducted within multidisciplinary project teams, each focussing on a priority issue. Current research priorities include: the fate and effects of toxic chemicals in the Great Lakes and the St. Lawrence River; groundwater contamination; accumulative effluent impacts in rivers; acid rain; lake rehabilitation; aquatic effects monitoring; ecotoxicology; and risk prediction methodologies.

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NWRI Digest

The *NWRI Digest* is the public newsletter of the National Water Research Institute. Suggestions, comments and further enquiries concerning newsletter items are welcomed. Please write to:

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Environment Week

June 2 - 8

Mark your calendars for Environment Week 1991! This year, in cooperation with the Burlington Cultural Centre, NWRI will present "**Reading the Waters**". The montage will explore the parallels between science and art using the environmental decline and hopeful future of the Hamilton Harbour as the common subject matter. Several NWRI scientists and local artists will lend their creative talents to the display.

The montage will be open May 26 to June 27 at the Burlington Cultural Centre. For more information, contact Farrell Boyce, Lakes Research Branch, at (416) 336-4921.

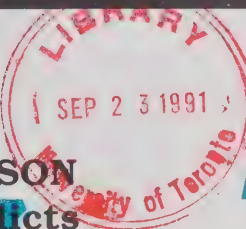
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THE NEWSLETTER OF THE NATIONAL WATER RESEARCH INSTITUTE

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RAISON
predicts
effects of
acid rain

**Supercritical
fluid
extraction**

**Sizing
up
cascade
filtration**

**Coal tar
in
Hamilton
Harbour**

Toxic Chemicals in the Great Lakes and Associated Effects

What does it all mean?

The presence of persistent toxic chemicals in the Great Lakes, and in particular their effect on the environment and human health, poses a series of questions for scientists and the public alike. The answers to many of these lie in the recently released report entitled *Toxic Chemicals in the Great Lakes and Associated Effects*. This document summarizes the current state of scientific knowledge on the levels of toxic chemicals in the Great Lakes and their effects on fish, wildlife and human health.

Dr. Rod Allan, Director, Lakes Research Branch, and Alison Ball, compiled and wrote Chapter One of the technical report which discusses the levels and trends of toxic chemicals in the water and sediments. The conclusions drawn from this chapter are encouraging.

Dr. Allan explains that present concentrations of toxic contaminants in the open waters of the Great Lakes are within objectives defined by the Canada/U.S. Great Lakes Water Quality Agreement, 1978 (GLWQA). These objectives are set to protect the most sensitive user (usually aquatic life) and are well below Canadian and international drinking water standards. Some of

the GLWQA objectives are exceeded on occasion in nearshore areas, in some of the channels connecting the lakes, and in the most heavily polluted areas which are defined as Areas of Concern by the International Joint Commission.

Toxic Chemicals in the Great Lakes and Associated Effects

Chapter One also discusses contaminants which have built up in the sediments. Lake bottom sediments contain much higher concentrations of contaminants than the overlying water.

Sediment core profiles reveal an historic account of the contamination. They show that the peak inputs of heavy metals and synthetic organic chemicals to the lake sediments occurred in the 1960s and 1970s, followed by declines in the 1980s. The concentrations of toxic substances in the sediments decreased sharply during the early 1980s, but now seem to be levelling off.

The substantial decline from the 1970s reflects increased regulation of the use of organochlorine pes-



ticides and polychlorinated biphenyls (PCBs). The slower improvement in water and sediment quality since the early 1980s is in part due to the continued input of toxic substances into the Great Lakes from the atmosphere and other non-point sources like groundwater. Many of the IJC-designated critical pollutants, such as PCBs, mercury and cadmium, enter the Great Lakes through rainfall.

Previously contaminated sediments are another source of toxic chemicals. When these sediments are disturbed, the chemicals associated with them may be recycled back into the water column.

Health Concerns

Toxic Chemicals in the Great Lakes and Associated Effects was written jointly by three federal departments. While Environment Canada contributed information on water and sediment quality, Health and Welfare Canada, and the Department of Fisheries and Oceans examined health concerns for humans and fish. As with water and sediments, the levels of contaminants in fish and aquatic birds decreased substantially from those reported in the 1970s but have remained relatively constant since the early 1980s.

Some fish, reptiles and mammals have exhibited reproductive and developmental problems and still have relatively high levels of contaminants. However, most previously affected bird species are reported to have shown recovery, and the remaining problems are

confined to a few highly contaminated areas.

The report concludes that Canadians living in the Great Lakes Basin do not have higher contaminant levels in their tissues than people in other parts of North America. It cautions that people who consume large quantities of contaminated fish or wildlife should reduce their intake in accordance with current advisories.

The peak inputs of heavy metals and synthetic organic chemicals to the lake sediments occurred in the 1960s and 1970s, followed by declines in the 1980s

Although elevated levels of toxic contaminants in the Great Lakes Basin do pose a threat to human health, the nature and extent of this remains unclear. Infants of nursing mothers can be exposed to greater than average amounts of contaminants from their mother's milk. Breast milk is relatively high in fat and consequently can contain fat-soluble organochlorine chemicals.

Where to get more information

Toxic Chemicals in the Great Lakes and Associated Effects is available in many forms. Technical Volumes I and II represent a compendium of

research findings aimed at a scientific audience. A Synopsis of these reports summarizes the information for a general audience. Copies of the report are available by writing to Environment Canada, Communications Directorate, Ontario Region, 25 St. Clair Avenue East, 6th floor, Toronto, Ontario, M4T 1M2.

Chapter One of the technical report has recently been published as a special issue of the *Water Pollution Research Journal of Canada* and can be obtained from the Canadian Association on Water Pollution Research and Control, and the National Water Research Institute

The extensive bibliography contained in the issue can also be obtained on floppy disk for use on a microcomputer. This software allows searches to be conducted in natural language, fields such as title, abstract and index terms. Desired key words can be combined using AND, OR, and NOT.

Contact

Dr. Rod Allan

References

Allan, R.J. and A.J. Ball. 1990. An Overview of Toxic contaminants in Water and Sediments of the Great Lakes. *Water Pollution Research Journal of Canada*. **25(4)**:387-505.

Environment Canada, Department of Fisheries and Oceans, and Health and Welfare Canada. 1991. *Toxic Chemicals in the Great Lakes and Associated Effects*, Volume 1: Contaminant Levels and Trends. 488p., Volume 2: Effects. 755p., Synopsis. 51p.



RESEARCH NEWS

RAISON predicts effects of acid rain

Drop by drop, acid rain eats away at our buildings, destroys our forests and endangers aquatic life in our lakes and streams. The RAISON (Regional Analysis by Intelligent Systems ON a microcomputer) expert system has joined the fight against acid rain. The expert system was used to predict the effects of acid rain control measures on lakes in eastern Canada. This information forged the backbone of the Aquatic Effects section of the *1990 National Long-Range Transport of Air Pollutants (LRTAP) and Acid Deposition Assessment Report*.

RAISON simulations provided critical information for the Canadian team negotiating with the U.S. for reductions in sulphur dioxide emissions

Acid rain is caused mainly by industrial emissions of sulphur dioxide and nitrogen oxides. The RAISON system was used to predict the effect of different sulphate loadings on lakes in each of 22 subregions of eastern Canada. Each subregion consists of lakes with similar geochemical properties and sulphate deposition patterns.

Experts refer to the concept of "critical loads" to denote the highest amount of wet sulphate a particular lake can withstand without suffering long-term harmful effects on the

ecosystem. In this case, the critical load was defined as the maximum amount of wet sulphate that would not force the acidic level of a lake to fall below a pH of 6.0.

The RAISON system brought together vast amounts of information on soil, air and water characteristics to predict the percentage of lakes in each subregion that would exceed their critical loads, given a specific annual deposition of wet sulphate. This does not include lakes that are already acidic due to natural processes.

Environmental managers can use this information to target desired reductions in sulphate deposition. RAISON simulations provided critical information for the Canadian team negotiating with the U.S. for reductions in sulphur dioxide emissions. These talks led to the signing of the Canada/U.S. Air Quality Agreement earlier this year.

The simulations do not take into account the contribution of nitrogen oxides to the acidification of lakes because there is a lack of reliable data regarding their fate and effects in the environment. Future models will focus on quantifying and predicting the impact of this factor in aquatic ecosystems.

Contact
Dr. David Lam

Reference
Federal/Provincial Research and Monitoring Coordinating Committee (RMCC). 1990. *The 1990 Canadian Long-Range Transport of Air Pollutants and Acid Deposition Assessment Report*, Part 4: Aquatic Effects



Evaluating benthic invertebrate indices

Indices of benthic invertebrate community structure are widely used to assess the impact of municipal and industrial ("point-source") effluents on stream and river ecosystems. However, surprisingly little information is available on the response of aquatic invertebrate communities to pollution from non-point sources like agriculture. Janice Metcalfe-Smith, Rivers Research Branch, and Dr. David Barton, compared several benthic invertebrate indices in terms of their ability to assess agricultural and municipal pollution in Quebec's Yamaska River and its tributaries.

The study revealed that most benthic indices currently used to assess the impact of sewage on aquatic systems were generally inadequate to describe the impact of agricultural pollution. Only two of the seven indices performed consistently well, while the rest lacked either sensitivity or reliability. But more importantly, the reliable results from the study indicated that the impact of agricultural practices on the river ecosystem was as severe as the effects of municipal and industrial discharges.

Contact
Janice Metcalfe-Smith

Reference
Barton, D.R. and J.L. Metcalfe-Smith. 1991. A comparison of sampling techniques and summary indices for assessment of water quality in the Yamaska River, Quebec, based on benthic macroinvertebrates. *Environmental Monitoring and Assessment* (in press).

Sizing up cascade filtration

Suspended sediment particles have long been recognized as important vectors for transporting contaminants in aquatic systems. Recently it has been demonstrated that the smaller and organic-rich fractions are the most important in the transport and ultimate fate of toxics. These fractions include relatively unstable and reactive flocculent and colloidal "particles".

The size of such particles is controlled by the amount of contaminants, organics and bacteria associated with them. In order to study these particulate fractions, it is necessary to sub-divide the total suspended sediment according to size. Research by a team of NWRI scientists has revealed that the traditional particle size fractionation technique doesn't "size up".

Dr. Bommanna Krishnappan, Dr. Ed Ongley, Dr. Salem Rao and Ian Droppo, Rivers Research Branch, tested the effectiveness of the traditional cascade filtration method for the separation of silt and clay size particles. This technique consists of passing a sediment/water mixture through a series of filters arranged in a descending order of filter pore size.

When results from this method were compared with data obtained from a non-intrusive laser particle size analyzer, the traditional cascade filtration technique was found to be inadequate for separating organic particles. Clogged filters and variability in filter pore sizes are causes for the overly wide spectrum of particle sizes retained in each fraction. Moreover, the physical stress of passing the samples over several filters disrupts many large particle aggregates, fragile colloids and flocculents.

Alternate methods for size fractionation of suspended particles are now being investigated by Dr. Rao and his associates. One promising technique is based on a flume system whereby water samples flow **over** the filters rather than being poured **on** them. This disturbs the particles to a lesser degree and allows them to be studied in a condition closer to their natural state.

Contact

Dr. Bommanna Krishnappan

Reference

Krishnappan, B.G., Droppo, I.G., Rao, S.S., and E.D. Ongley. 1991. Testing of a filter fractionation technique using Malvern particle size analyzer. NWRI Contribution 90-157.

Supercritical fluid extraction

A new tool for environmental scientists

From coffee decaffeination to quality control in the pharmaceutical industry, supercritical fluid extraction (SFE) is making its mark as a preferable alternative to traditional extraction methods using organic solvents. Dr. Francis I. Onuska, Research and Applications Branch, along with scientists from Dearborn Chemicals Inc., is working on ways to exploit the advantages of this rapidly developing technology for use in environmental chemistry. SFE promises to make the extraction of toxic organic pollutants from difficult environmental samples faster, safer and more efficient.

A supercritical fluid is a dense gas that has been heated beyond its critical temperature. Beyond this temperature the fluid can no longer be liquified by pressure. The density of a supercritical fluid approaches that of a liquid, making it a potent solvent. But since it is less viscous than a liquid, it can diffuse more readily.

Some compounds, such as carbon dioxide and nitrous oxide, have very low critical temperatures and pressures which can easily be maintained using commercially available laboratory equipment. This makes them ideal candidates for extracting volatile organic pollutants, such as polynuclear aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) from even demanding environmental samples.

Fly ash from municipal incinerators is a significant source of entry of polychlorinated dibenzo-p-dioxins (PCDDs) into the environment and is perhaps the most difficult extraction matrix. The ash is formed during the combustion of garbage and consists of 99 per cent inorganic matter. PCDDs are usually recovered from fly ash by solvent extraction in a Soxhlet apparatus, followed by lengthy cleanup and concentration steps. The whole process can take anywhere from six to 24

hours. It also requires large amounts of some toxic solvents like methylene chloride.

Dr. Onuska has developed a procedure that reduces the extraction time to 2.5 hours per sample by using supercritical nitrous oxide and its mixtures with methanol or toluene. The process recovers a larger fraction of the pollutant and a smaller amount of solvent is necessary, reducing the risk of exposure for laboratory personnel. Moreover, pure nitrous oxide is relatively inert, eliminating contamination of the extract by solvent residue.

Supercritical fluid extraction can also be tailored to maximize extraction of target compounds. The density of a supercritical fluid is directly related to its power as a solvent. So by altering the temperature and pressure, the density of the fluid can be adjusted to exclude unwanted

See SFE pg 6

Coal tar in Hamilton Harbour

Black ribbons of coal tar contaminated sediments extend out into Hamilton Harbour, originating from an area near Randle Reef. This is one finding of a recently completed study which maps the distribution of coal tar in the harbour.

Dr. Tom Murphy and a team of scientists from the Lakes Research Branch analyzed data from 81 sediment cores collected from sites in Hamilton harbour. While the coal tar contamination did vary with location, there was one area of extremely high concentration adjacent to the southwest Stelco outfall and the Hamilton-Wentworth combined sewer outfall. The sediments around this region are jet black and shiny.

Coal tar contamination is of concern because of its high content of polynuclear aromatic hydrocarbons (PAHs), a class of compounds which include such carcinogenic and toxic chemicals as benzo (a) pyrene. The sediment core study revealed that approximately 70,000 m³ of bottom sediments between Randle Reef and the Stelco outfall

contain total PAHs at concentrations greater than 200 µg/g. In three bioassays conducted using harbour sediments, 50 per cent of test organisms were found to die at total PAH levels of 200 µg/g.

The sediments around this region are jet black and shiny

The sublethal effects of PAHs can also be an environmental hazard. These compounds have been reported to trigger cancer in wildlife at concentrations below that of acute toxicity. Moreover, the coal tar hotspot near Randle Reef lies in shallow water where barges and boats resuspend the sediments, providing a source of recontamination for the harbour.

The highest concentrations of coal tar were found in deeper layers of the sediments, indicating historic origins which have diminished in recent times. The high naphthalene content of the coal tar suggests that a possible historic source is the

process water from coke ovens used in the steel industry. It remains uncertain how much of the coal tar could have originated from the sewer outfall.

The report recommends dredging the most heavily contaminated sediments (those above 200 µg/g). In fact, pilot scale treatments of the contaminated sediments have already begun. It is necessary that these and other carcinogenic substances be dealt with before the Remedial Action Plan goal of a healthy fishery can be realized.

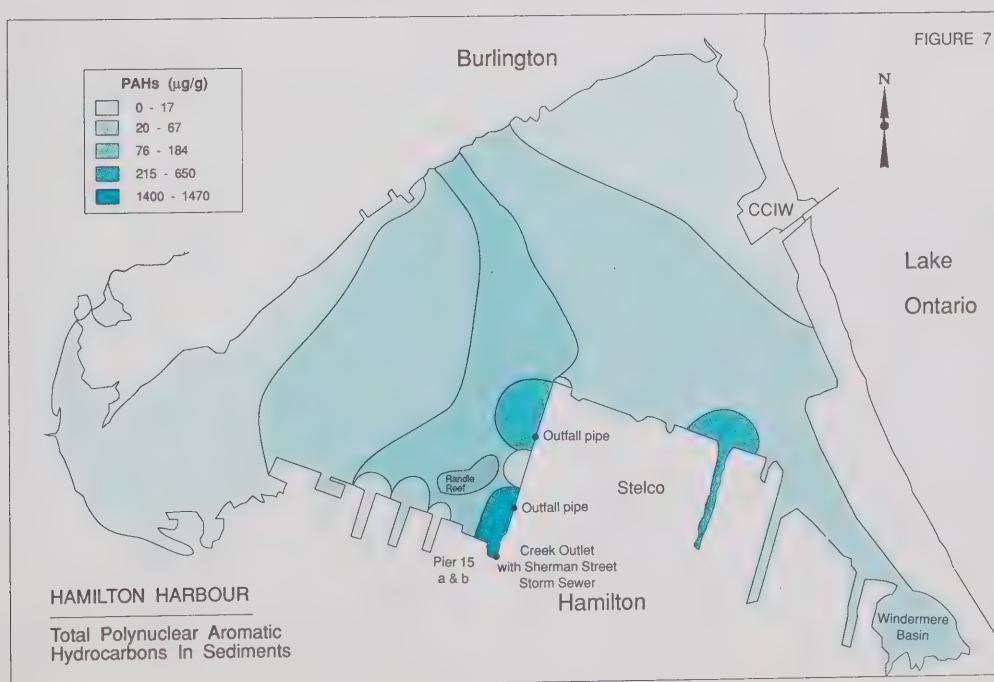
Although the study was undertaken by the Lakes Research Branch, it was initiated through financial assistance from Stelco and funded in part by the Cleanup Fund of Environment Canada's Great Lakes Action Plan.

Contact

Dr. Tom Murphy

Reference

Murphy, T.P., Brouwer, H., Fox, M.E., Nagy, E., McArdle, L. and A. Moller. 1991. Coal tar contamination near Randle's Reef, Hamilton Harbour. NWRI Contribution 90-17.



DNAPLs pose challenges for groundwater clean up

The groundwater in the vicinity of the Special Waste Compound at the Gloucester Landfill site near Ottawa is contaminated by hazardous wastes; principally organic solvents. A recently published Inland Waters Directorate Scientific Series report describes a hydrogeological investigation of the contamination, undertaken by scientists from the Rivers Research Branch. The report focusses on remedial alternatives and concludes that the presence of nonaqueous phase liquids (NAPLs) will require cleanup measures beyond traditional pump and treat methods.

NAPLs come in two types: light nonaqueous phase liquids (LNAPLs) that float at the top of the aquifer (e.g. gasoline), and dense liquids (DNAPLs) which sink to the bottom. Of the contaminants found in the Gloucester aquifer, it is the DNAPLs such as trichloroethene (TCE) and tetrachloroethene (PCE) that are of primary significance.

DNAPLs like TCE can be present in three forms in the ground-water. Imagine pouring a cupful of water onto a sponge which is resting on a table. Some of the water will work its way through the sponge and form a puddle at the base, while the rest of it remains trapped in the pores. In the same way, DNAPLs can form pools at the bottom of an aquifer or adhere to soil particles to form "ganglia".



Photo by Dr. Allan Croue

Steve Shikaze, a former student employee at NWRI, obtains groundwater for analysis of organic chemicals using a multilevel sampler located on the Gloucester Landfill site.

DNAPLs and LNAPLs can also dissolve in the groundwater. This dissolved state is the reason aquifers contaminated by DNAPLs can never be fully restored by merely pumping and treating the water. DNAPLs typically have very low solubilities and dissolution rates in water: a pool of the liquid may take hundreds of years to totally dissolve. Even if an aquifer is pumped and treated until it appears that the groundwater is essentially free of contaminants, the DNAPLs from the ganglia or pools will redissolve and recontaminate the groundwater after the pumping stops.

The presence of DNAPLs has been blamed for the failure of the U.S. Superfund program to treat hazardous waste sites. The program has recently received a great deal of criticism for its reliance on pump and treat methods.

NWRI scientists detected the dissolved phase of many DNAPLs in the Gloucester aquifer. Although DNAPLs are unlikely to exist as pools in this particular aquifer, they are probably present as ganglia. To further complicate matters, aside from site excavation of shallow DNAPLs, there is no other proven method for efficiently removing DNAPLs from aquifers.

The sequence of remediation recommended in the report is as follows: (1) excavate the shallow till contaminated by ganglia, (2) pump and treat to remove the dissolved DNAPLs and (3) utilize *in situ* bioremediation after pump and treat methods have removed the majority of contaminants.

In situ bioremediation is a "natural" process whereby microorganisms existing in the aquifer break down the contaminants for use as a food source. Scientists and engineers can boost this process by injecting nutrients and oxygen into the aquifer to stimulate microbial growth. If this method works, it may offer a cost-effective alternative to continuously pumping

and treating the groundwater, provided the concentrations have already been reduced as much as possible by treating the water.

The ten-year NWRI study was funded by Transport Canada and Environment Canada. It represents one of the first and most detailed studies on how to effectively investigate a contaminated site.

Contact

Kent Novakowski

Reference

Jackson, R.E., Lesage, S., Priddle, M.W., Crowe, A.S., and S. Shikaze. 1991. Contaminant hydrogeology of toxic organic chemicals at disposal site, Gloucester, Ontario, Part 2. Remedial Investigation. Inland Waters Directorate Scientific Series 181, Inland Waters Directorate, Ottawa, Ontario, 68 pp.

SFE *cont'd*

pounds and increase recovery of the desired pollutant.

Another advantage of SFE is the ability to couple it with organic analysis. Dr. Onuska has linked SFE with high resolution gas chromatography. The automated technique minimizes the amount of extract lost through handling and provides quantitative data with an improved precision at a fraction of the analysis time per sample. One disadvantage is that the cost of SFE equipment is still relatively high, inhibiting its use as a routine method in environmental analysis.

The future of SFE is bright and holds great promise in the field of environmental chemistry. Dr. Onuska reviewed recent advances in SFE at the 13th International Symposium on Capillary Chromatography, held during May in Riva del Garda, Italy.

Contact

Dr. Francis Onuska

References

Onuska, F.I. and K.A. Terry. 1991. Supercritical fluid extraction of polychlorinated dibenzo-p-dioxins from municipal incinerator fly ash. NWRI Contribution 91-104.
Onuska, F.I. and K.A. Terry. 1989. Supercritical fluid extraction of PCBs in tandem with high resolution gas chromatography in environmental analysis. *J. High Resolut. Chromatogr.* **12**: 527-531. [also: NWRI Contribution 89-124]

IN BRIEF

IAGLR Mott Fellowship Award



Each year, the Mott Foundation awards fellowships to two M.Sc. students and one Ph.D. student from both Canada and the U.S. through the International Association for Great Lakes Research (IAGLR). The awards are directed to students undertaking research dealing with environmental problems of the Great Lakes. The recipients for this year's Canadian M.Sc. awards are Todd Williams (left) and Mark Hewitt (right), both graduate students under the co-supervision of Dr. George Dixon at the University of Waterloo and Dr. John Carey at NWRI. Both students are conducting research related to the impact of pulp mill discharges on aquatic receiving environments.

Techniques for sampling aquatic sediments

Alena Mudroch, Lakes Research Branch, recently prepared a handbook on techniques for aquatic sediments sampling. The handbook describes sampling techniques for bottom sediments, suspended sediments and sediment pore water. It also identifies procedures for handling recovered samples prior to physico-chemical analyses and other tests. The monograph

provides an up to date "how-to" text for professionals interested in defining the physical and chemical characteristics of aquatic sediments and their effects on aquatic ecosystems.

Reference

Mudroch, A. and S.D. MacKnight, eds. 1991. *Handbook of Techniques for Aquatic Sediment Sampling*. Boca Raton, FA: CRC Press Inc., 210p.

Achieving excellence

The Departmental Citation of Excellence was awarded to Dr. Jim Maguire and Richard Tkacz (posthumously), Rivers Research Branch, for their research on tributyltin, an extremely toxic antifouling pesticide used on boats, ships and docks. This work led to the regulation of tributyltin in Canada.



Catching the wave

Waves are an important factor in shore erosion and must be considered in the design of coastal structures like marinas and breakwaters. Dr. Michael Skafel and Craig Bishop, Research and Applications Branch, used measured data from the Great Lakes and Gulf of St. Lawrence to test the abilities of several existing models to predict wave dimensions and direction. They found acceptable results for wave height and period, but noticed that predictions for wave direction were not always reliable. Further evaluation of these models continues.

Reference

Skafel, M.G. and C.T. Bishop. 1991. Comparison of wave climate models. NWRI Contribution 91-101.



NWRI *Digest* is the public newsletter of the National Water Research Institute, Canada's largest freshwater research establishment. The institute conducts a comprehensive program of research and development in the aquatic sciences which it undertakes in partnership with water management agencies and water science communities in Canada and around the world. Our research creates knowledge and develops expertise on water quality issues important for sustainable water resource use and the preservation of freshwater ecosystems.

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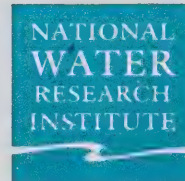
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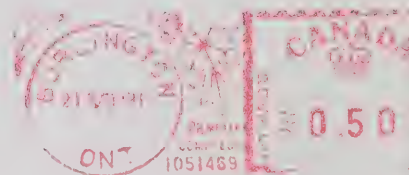
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THE NEWSLETTER OF THE NATIONAL WATER RESEARCH INSTITUTE

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3
Drawing the
line...Benthic
invertebrates
help define
contaminated
sediments

4
Underwater
clouds

5
Measuring
herbicide
damage
to algal
communities

6
The myth of
the Canadian
Arctic

Environmental impact of bleached kraft mill effluents

Studying the myriad environmental effects of pulp mill effluents is like opening a Pandora's box. The several hundred compounds already identified in pulp mill effluent comprise only a small fraction of the total amount of organic material discharged. To complicate the problem, the individual toxicities of many of these compounds remains unknown.

Concern over the health of fish in receiving waters, combined with proposals for several large pulp mill operations in Alberta, has pushed the environmental effects of pulp mills to the forefront of national interest and the federal legislative agenda.

The *Canadian Environmental Protection Act (CEPA)* recognizes effluents from pulp mills using bleaching as substances requiring formal assessment and possible regulatory control under its Priority Substance List published in 1987. Dr. John Carey, Director of the Rivers Research Branch, is a member of the federal panel assessing the potential of pulp mill effluents to cause environmental harm. The assessment report is scheduled for release this fall. Research to evaluate the environmental impact of pulp mill effluents is conducted by NWRI scientists to support the CEPA.

Most of NWRI's research in this area is directed at environmental pathways of pulp mill-related organics, particularly those responsible for sublethal effects on fish populations. Sublethal effects are those that negatively impact on an organism's general health or reproductive abilities without necessarily killing it.

The interest in sublethal effects stems from recent advances in this area of study. For instance, the ability to measure the presence of mixed function oxygenase enzymes (MFOs) in fish livers has developed over the last decade. These enzymes are induced by the presence of specific foreign compounds and can be used to indicate exposure of fish to these substances.

One of the first major investigations into the sublethal effects of pulp mill effluents was the Environment/Cellulose project established by the Research Council of the Swedish National Environment Protection Board. The study examined the biological effects of bleached kraft mill effluents on the Gulf of Bothnia aquatic ecosystem, with a major emphasis on biologically active organic compounds such as chlorinated dioxins and furans.

The Swedes noticed various effects on aquatic populations in the



receiving waters, including reduced reproduction and abnormal physiology in fish. The presence of considerable concentrations of organochlorines suggested that these compounds may be responsible for the observed effects, although no cause and effect relationship was demonstrated.

The Swedes attempted to correct the problem by controlling the amount of adsorbable organic halogens (AOX) discharged by the pulp mills. AOX is a non-specific parameter measuring the total amount of organochlorines. This ranges from high molecular weight chlorinated lignin to lower weight lignin degradation products. Chlorinated dioxins and furans make up less than 10^{-6} of the total chlorinated organics. In 1988, NWRI launched a major research program to study the environmental impacts of bleached kraft mill effluents and to investigate whether AOX is a suitable parameter for regulating pulp mill effluent impacts in Canadian receiving waters. The project, headed by Dr. Carey, has three main objectives:

- 1) to determine whether the same type of effects the Swedes reported would occur in Canada;
- 2) to ascertain whether recent changes in process and effluent treatment in modern Canadian mills can effectively eliminate these effects; and
- 3) to determine if a cause and effect relationship exists between AOX and the observed effects, thus determining whether AOX is an useful surrogate parameter for regulatory purposes.

The answer to the first question was obtained from a field study in the Saint-Maurice River, near La Tuque, Quebec, headed by Dr. Carey and Dr. Peter Hodson of the Institute Maurice Lamontagne in Mont-Joli, Quebec. Not only did the scientists observe Swedish-style effects on white sucker populations, they also observed changes in steroid hormones that could have indicated reproductive failure and led to changes in populations. In another field study, Dr. Mark Ser-

A spectrum of chemicals

One of the reasons behind the wide array of compounds found in pulp mill effluents is the number of reactions at each stage in the pulp and paper making process, each producing their own set of chemicals.

Wood, the major raw material in pulp mill operations, is composed of cellulose, hemicellulose, lignin and extractives (those substances that can be extracted with organic solvents.) Lignin lends rigidity to wood and is removed during the pulping process to facilitate paper-making.

Today, the majority of mills employ what is known as kraft chemical pulping. Within digesters, wood chips are treated with sodium sulfate and sodium hydroxide under elevated temperatures and pressures, dissolving about 90 to 95 per cent of the total lignin. This process produces an alkaline pulping liquor which also contains some wood extractives and acids resulting from the breakdown of celluloses and hemicelluloses.

A multistage bleaching process is used to remove the remaining lignin to produce the desired pulp brightness. Chlorination of residual lignin results in the formation of a vast number of chlorinated organic compounds, many of which are toxic, can bioaccumulate, and resist degradation. Moreover, these compounds react with other organic compounds already present in the streams, further increasing the array of chemicals which can potentially cause harm to aquatic ecosystems.

vos, of the Great Lakes Laboratory for Fisheries and Aquatic Sciences, and Dr. Carey are jointly examining the Spanish River in Espanola, Ontario, to determine whether the technology used at this modern mill can eliminate the observed effects in fish. The Espanola mill utilizes oxygen delignification, chlorine dioxide substitution and secondary treatment, and discharges AOX at

levels below that of other Canadian kraft mills. For this reason, it is considered to be one of the best mills in Canada.

In spite of the advanced technology employed at the mill, the researchers still found elevated levels of liver somatic indices and mixed function oxygenase in white sucker populations downstream of the mill. The low dilution factor in the Spanish River may account for some of these effects. The results suggest, however, that modern technologies may not reduce the concentrations of harmful compounds to negligible levels.

Dr. Carey also heads a study which will attempt to ascertain which components of pulp mill effluents are causing sublethal effects in fish. Preliminary results indicate that the compounds causing elevated levels of MFOs in fish livers appear to be low molecular weight, water soluble compounds. Since AOX is primarily composed of high molecular weight material, this could mean that AOX may be inappropriate for use as a surrogate parameter.

Drs. Carey and Servos, along with their research teams, will summarize their current research at the Aquatic Toxicity Workshop in November, in Ottawa, and at the 12th annual meeting of the Society for Environmental Toxicology and Chemistry (SETAC) in Seattle.

Contact

Dr. John Carey

References

Anders Sodergren, ed., 1989. *Biological Effects of Bleached Pulp Mill Effluents*. Bratts Tryckeri AB, Jonkoping. 139 pp.

Hodson, P.V., Dodson, J.J., Couillard, M.C., Gagnon, M.M. and J.C. Carey. 1990. Biochemical, physiological, pathological and population responses of white sucker (*Catostomus commersoni*) to bleached kraft mill effluents in the Saint-Maurice River, Quebec. Presented at the 11th annual meeting of the Society for Environmental Toxicology and Chemistry, Washington, D.C., November 1990. Submitted to *Environmental Toxicology and Chemistry*.

Continued on p. 4

RESEARCH NEWS

Drawing the line

BENTHIC INVERTEBRATES HELP DEFINE CONTAMINATED SEDIMENTS

Contaminated sediments have long been a major concern in many areas of the Great Lakes, but what does "contaminated" mean in a biological sense? In the past, this question was answered in terms of a series of chemical parameters—target concentrations of specific pollutants based on toxicity data.

Recent years have witnessed a gradual realization that chemical monitoring alone may not be enough to adequately describe the complex effects of pollutants on aquatic ecosystems. NWRI scientists recently began a study to categorize the level of contamination in sediments of the Great Lakes, based on biomonitoring with benthic invertebrates. The research will support development of biological sediment quality guidelines.

Dr. Trefor Reynoldson, Lakes Research Branch, and Dr. Kristin Day, Rivers Research Branch, are leading a team of scientists developing benthic invertebrate indices for the Great Lakes. Emphasis is placed on the Areas of Concern, most of which contain sediments contaminated with heavy metals, toxic organic chemicals, or both.

Benthic organisms are good biomonitors for contaminants since they spend all or part of their life cycle in the sediments. This prolonged exposure means that any contaminant-associated problems will likely be manifested in them first.

The study will look at developing reference communities and bioassay responses of benthic invertebrates. Data will be collected on sediment toxicity and benthic in-

vertebrate community structure at numerous uncontaminated sites along the Great Lakes. Multivariate analyses will be used in conjunction with other statistical techniques to develop indices to describe community structure for these uncontaminated sites and to develop predictive models for determining community structure and response in toxicity tests. These models will be used to predict the ideal communities at other sites for undisturbed conditions. This can then be compared to the existing community structure which has developed over the years as a result of exposure to specific pollutants. Biological criteria derived from the reference sites can be compared to the values at sites where contamination is suspected to determine the need for remediation or the suitability of disposal options for dredged sediments.

Over 50 uncontaminated sites along the Great Lakes will be sampled in the pilot project this fall. The scientists will look at reproductive or survival data for different organisms: *Chironomus riparius*, *Hyallela azteca*, *Hexagenia limbata*, and *Tubifex tubifex*. All of these organisms were chosen because of their biological significance in the Great Lakes and the existence of well-established sampling and assay techniques for each.

At the end of the three-year study, Reynoldson hopes to have comprehensive data on these organisms from over 250 different sites. All the sites are nearshore, under 30 meters deep and are composed of fine sediments. This focuses the study on areas that are accessible to remedial measures.

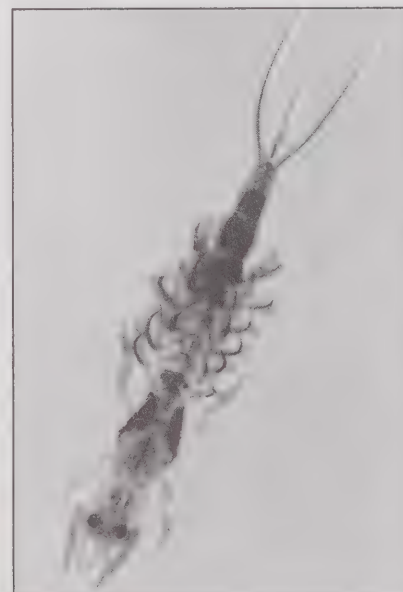
However, while biology can tell you that there is a problem, it does not necessarily tell you what that problem is. That is why the study includes strong chemical and physical components, although the final outcome will be a set of biological criteria. The value of chemical and physical data is paramount when determining causes of contamination and the appropriate remedial technology. This study aims to put together the various aspects of biology, physics and chemistry essential to an ecosystem-based approach.

Contact

Dr. Trefor Reynoldson

Reference

Reynoldson, T.B. and K.E. Day. 1991. A Study Plan for the Development of Biological Sediment Quality Guidelines (NWRI unpublished report available upon request).



A closeup look at *Hexagenia limbata*, a benthic invertebrate used to biomonitor contaminated sediments. (Specimen courtesy of Donna C. Bedard.)

Quality assurance in biological testing

The basic principles of quality assurance (QA) are the same for both biological and chemical laboratories. However, the diverse, less standardized nature of biological testing requires development of unique guidelines. To respond to this need, Alfred Chau, Research and Applications Branch, chaired a small group of experts who recently produced a report entitled "QA Guidelines for Biology in Aquatic Environmental Protection".

The report provides guidance on designing and implementing QA programs for biological measurement. It describes the basic elements of an internal Quality Assurance/Quality Control program, based on the principles of good laboratory practice. The report then goes on to describe the application of these principles in specific biological subject areas such as aquatic toxicity testing, paleolimnology, benthic community studies and microbiological assessment.

The document is intended as a generic guide and must be tailored by individual users to meet their specific objectives. The document will be updated periodically as knowledge of biological quality assurance evolves.

Contact

Alfred Chau

Reference

Hart, D., 1991. QA Guidelines for Biology in Aquatic Environmental Protection, NWRI, Burlington, Ontario, 123 pp.

UNDERWATER CLOUDS

A cloud of fine particles, called the nepheloid layer, moves in suspension above the bottom of Lake Ontario. Alena Mudroch, Lakes Research Branch, recently completed a study characterizing this phenomenon and evaluating its role in the transport of contaminants across the lake. Her findings indicate that the presence of this layer may slow the recovery of the lake even after the quantity of contaminants entering the lake is reduced.

The nepheloid layer is a region of suspended particulate matter formed by natural processes. It appears in the summer and remains until the turnover of the lake in the fall. This phenomenon was first noted by oceanographers in various regions of the world oceans.

The nepheloid layer in Lake Ontario was discovered in the early 1980s during reconnaissance of the *Scourge* and the *Hamilton*, two battleships which sank in Lake Ontario during the War of 1812. Jacques Cousteau's colleagues viewed the two shipwrecks from a submersible and commented that the water at the bottom of the lake looked like "pea soup". This prompted scientists to study the phenomenon, which was later found to be a thick layer of suspended particles, consisting mainly of silica, calcite, and organic matter.

Results from Mudroch's most recent study reveal that the nepheloid layer in Lake Ontario becomes enriched with various metal and organic contaminants. In comparison to bottom sediments, the nepheloid layer contains higher concentrations of lead, zinc and copper. The concentrations of total polychlorinated biphenyls (PCBs), particularly lower chlorinated biphenyls (tetra and pentachlorobiphenyls), were also elevated.

The nepheloid layer begins to form in July and grows until it reaches a maximum thickness of approximately 40 m in September. After the autumn turnover, the suspended matter becomes mixed throughout the water column. The dissolution and decomposition of particles from the nepheloid layer at this time may recycle the contaminants back into the water and bottom sediments.

These natural processes may lengthen the time for Lake Ontario to respond to the reduction of point source loadings of contaminants. Future studies will investigate the effects of currents in the transport of particles in the nepheloid layer.

Contact

Alena Mudroch

Reference

Mudroch, A. 1991. Geochemical composition of the nepheloid layer in Lake Ontario. NWRI Contribution 91-23.

Continued from p. 2

Servos, M., Carey, J., Ferguson, M., Van Der Kraak, G., Ferguson, H., and J. Parrott. 1991. Impact of a modern bleached kraft mill on white sucker populations in the Spanish River, Ontario, Canada. Presented at the 26th Canadian Symposium on Water Pollution Research, Burlington, Ontario, February 1991. Submitted for publication in *Water Pollution Research Journal of Canada*.

Williams, T.G., Carey, J.H., Parrot, J.L., Burnison, B.K., and D.G. Dixon. 1991. The effects of concentrated pulp mill effluents on mixed function oxygenase (MFO) activity in rainbow trout. Presented at the 26th Canadian Symposium on Water pollution Research, Burlington, Ontario, February 1991. Submitted for publication in *Water Pollution Research Journal of Canada*.

Measuring herbicide damage to algal communities

Algae are important components of freshwater ecosystems which can be quite sensitive to damage by herbicides due to their similarity to the target organisms of these chemicals. Dr. Kristin Day, Rivers Research Branch, assessed a method for determining the acute short-term effects of low concentrations of herbicides on the photosynthetic activity of algae living in freshwater streams.

Dr. Day retrieved algal communities attached to submerged rocks in Limestone Creek, southern Ontario, and placed them in a specially constructed bankside incubator. The incubator is constructed to measure oxygen production under dark and light conditions while mimicking the stream environment. This indirect method for determining photosynthetic ability is in itself an indication of primary production and health of the algal community.

The communities used in the study consistently displayed a marked decrease in oxygen production when subjected to herbicides which are known to inhibit photosynthesis and at concentrations found in surface runoff from agricultural and forested watersheds.

The incubator has been widely used in other biological investigations, but this study demonstrates its usefulness as a rapid, innovative, *in situ* technique for ecotoxicology studies. Furthermore, exposing the algal communities to high concentrations of herbicides for short periods of time allows for realistic representations of actual situations, since aquatic environments are known to receive pulsed doses of herbicides from accidental aerial overspray or rainstorm runoff.



Environmental chambers in a bankside incubator containing attached algae.

Future research will focus on determining whether this method can be modified to measure photosynthetic recovery after the algae-covered rocks are returned to the stream.

Contact
Dr. Kristin Day

Reference
Day, K.E., 1991. A method to determine the short-term effects of herbicides on primary productivity of periphyton in lotic environments. Presented at the 17th Annual Aquatic Toxicity Workshop, Vancouver, British Columbia, Nov. 5-7, 1990.

Volatilization

A pathway for pesticides

When pesticides are sprayed on crops or forests, some can inadvertently drift onto local bodies of water. Dr. Jim Maguire, Rivers Research Branch, has looked at the role of volatilization in pesticide transport from the thin, surface layer of the water.

Dr. Maguire studied the short-term fate of two pesticides (fenitrothion and deltamethrin) used on Canadian forests and/or agricultural crops. In laboratory tests on natural water, Dr. Maguire found that at least 70 per cent of the pesticide landing on the water surface quickly volatilized from the surface microlayer before it could be transported to deeper water. Volatilization was much slower when the pesticides were injected directly into the subsurface.

These findings suggest that volatilization from the surface microlayer is the major pathway for dissipation of these pesticides from natural waters.

Contact
Dr. Jim Maguire

Reference
Maguire, R.J. 1991. Kinetics of pesticide volatilization from the surface of water. NWRI Contribution 90-158. (Also accepted for publication in the *Journal of Agricultural and Food Chemistry*.)

TOXFATE 3.6 now available

TOXFATE is a mathematical model which predicts the fate of toxic contaminants in lake and river ecosystems, along with their concentrations in biota. The newest version of the program (3.6) runs on microcomputers and produces a graphic display for interactive use. The program is available free of charge upon request.

Contact
Dr. Efraim Halfon

The myth of the Canadian Arctic

Arctic ecosystem endangered by global pollution

The headline of a front page article in the *Los Angeles Times*, June 18, 1991, reads "In Arctic, a Toxic Surprise". This is only one of the most recent indications of problems to surface in the Canadian Arctic resulting from the global cycling of contaminants.

The long-held popular opinion that the arctic environment remains pristine has been set aside. While evidence of bioaccumulation of contaminants in the Arctic has been noted for several decades, only recent research has demonstrated that chemical contaminants, such as PCBs, DDT and toxaphene, are a persistent problem. These compounds are now commonly found in air, water, plants, wildlife and humans.

While local sources exist for some of these contaminants, the dominant source is transport over long distances by air and water from regions where they are used in industry and agriculture. The sensitivity of the arctic ecosystem to these contaminants remains unknown. Nevertheless, the unique climate of the region and its control over the biogeophysical characteristics of the ecosystem, the length of the food chain, the high proportion of body fat characteristic of arctic biota and the continuing dependence of the native population on natural food necessitate action to safeguard human health and the environment.

The Arctic Environmental Strategy

The Arctic Environmental Strategy announced in May, 1991, is an action plan designed to preserve and enhance the integrity, health, biodiversity and productivity of arctic ecosystems for the benefit of present and future generations.

The strategy is a key component of the federal Green Plan, reflecting the growing concern for the health of Canada's North and its people.

The Strategy, developed by the Department of Indian Affairs and Northern Development (DIAND), in consultation with other federal departments, territorial governments and native organizations, establishes four programs to be carried out over the next six years. These programs address key environmental challenges in the North:

- contaminants;
- waste (e.g., abandoned Distant Early Warning (DEW) Line radar sites, fuel drums);
- water quantity and quality; and
- environment/economy integration.

The Arctic Environmental Strategy will serve to enhance and augment research by the National Water Research Institute into arctic contaminants. Some of the Institute's prior research has targeted northward flowing watersheds with the potential to transport contaminants from the south (e.g., the Mackenzie River). However, other NWRI research on atmospheric deposition of organic contaminants to the annual snow pack across the North and to the Agassiz Ice Cap on Ellesmere Island has demonstrated the extensive and continuing delivery of contaminants from the atmosphere.

Contaminants carried from the south

As we learn more about the Arctic, we recognize that it has an unique geographic position with respect to atmospheric transport of contaminants, in which distance from

source may have little relevance. During the winter, the polar front moves south, permitting rapid transport northward of contaminants emitted to the atmosphere from the industrial and agricultural regions of North America and Eurasia.

Eurasia appears to be the primary source due to the more northerly location of agriculture and industry. Moreover, the Eurasian emissions move poleward as part of cold, dry air masses over frozen land and sea. This minimizes en route loss of contaminants from the atmosphere through precipitation.

In contrast, even in winter, many of the air masses from central and eastern North America move poleward over the open water of the Atlantic Ocean where precipitation scavenging continues to occur. Further evidence to identify Eurasia as a source of contaminants is the annual delivery to the Arctic of pesticides such as DDT. DDT has been banned from use in Canada and the U.S. for nearly two decades but is still widely used in Eurasia.

Northern challenges

The Arctic Environmental Strategy will provide new resources over the next six years to greatly expand the NWRI research activities north of 60°N. In cooperation with the Atmospheric Environment Service and contractors, a global inventory of pesticide use is being compiled. These data will provide the basis for an atmospheric emission, transport and delivery model to be developed for the North. Calibration of the model will be based on air concentration measurements



NWRI staff collect snow samples on Ellesmere Island for contaminant analyses.

and an expansion of the atmospheric deposition network maintained by NWRI.

An understanding of the air/snow exchange of these contaminants is essential to developing aquatic system delivery models and to evaluating the historical contaminant

records preserved in glaciers and peat bogs. These exchange and transformation rates will be addressed through field research and cold room simulation work undertaken at NWRI.

The fate of contaminants in the aquatic system, including transformation, degradation and loss due to biological, chemical and physical processes, will be investigated. Intensive, multi-disciplinary studies of small watershed will be utilized for this purpose. These data will be synthesized with

those from other related research to identify the fate of contaminants in northern aquatic systems and to estimate contaminant loadings to the marine environment.

This is an exciting undertaking involving collaboration between

NWRI and interdepartmental and international scientists. While past research in southern aquatic systems will provide tools and guides for the northern projects, the logistical problems, physical conditions and the unique biogeochemical relationships that dominate northern systems will provide many challenges.

Dr. Dennis Gregor
Research Scientist
Lakes Research Branch



CANADA'S GREEN PLAN
LE PLAN VERT DU CANADA

IN BRIEF

Environment Week display draws community



Four-year-old Hamilton native Stephanie Yates enjoys some hands-on learning about our environment at "Reading the Water", the Environment Week display held by NWRI and the Burlington Cultural Centre. The display depicted the present degradation and the hopeful future of Hamilton Harbour, and drew a perspective from both government scientists and local artists. It was held at the Cultural Centre from May 26 to June 27.

A call for local action

Jim Ryan, Research and Applications Branch, designed a poster entitled "The Global Environmental Crisis" as part of NWRI's Environment Week activities. The poster graphically highlights the urgent need for responsible environment stewardship at all levels of society. It was jointly sponsored by Environment Canada and the City of Burlington Sustainable Development Committee.

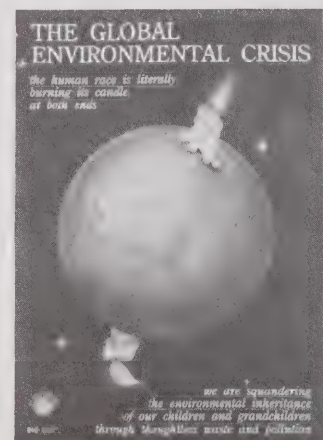
Ryan also wrote an article on sustainable development for *Municipal World*, an independent Canadian journal for municipal government. The article, entitled "Sustainable Development: Existing in Harmony with the Environment," focusses on the role of local government in implementing global sustainable development. The message behind the article is that only through concerted local action worldwide can we prevent the degradation of the planet's natural and environmental resources. It emphasizes the urgent need to incorporate sustainable development into the management, planning and decision-making processes of municipalities.

Contact

Jim Ryan

Reference

Ryan, J., 1991. Sustainable development: Existing in harmony with the environment. *Municipal World*, March 1991, pp 3-5.





NWRI *Digest* is the public newsletter of the National Water Research Institute, Canada's largest freshwater research establishment. The institute conducts a comprehensive program of research and development in the aquatic sciences which it undertakes in partnership with water management agencies and water science communities in Canada and around the world. Our research creates knowledge and develops expertise on water quality issues important for sustainable water resource use and the preservation of freshwater ecosystems.

Suggestions, comments and further enquiries concerning NWRI *Digest* are welcomed. Please write to:

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THE NEWSLETTER OF THE NATIONAL WATER RESEARCH INSTITUTE

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S**The speed of
water****Working
together
for our
environment****Chain Lake
residents
take action****Open House
1992****Developing ecosystem objectives
for the Great Lakes**

Imagine the Great Lakes Basin ecosystem as a pyramid of cans in a grocery store. Each can — birds, fish, plants, humans, microorganisms — is perched precariously on many others. In spite of its highly unstable appearance, the structure can be remarkably resilient. Some cans can be removed without seriously threatening the overall stability of the structure. However, it is impossible to predict which cans cannot be removed without causing the entire pyramid to collapse.

**The concept of man as
central to the
ecosystem, not separate
from it, is a vital
underlying principle of
the ecosystem approach.****A Way Of Thinking**

The concept of man as central to the ecosystem, not separate from it, is a vital underlying principle of the ecosystem approach. The approach breaks the barriers in compartmentalized thinking and recognizes the multitude of pathways and channels for interaction within an ecosystem. For example, if one were to simply target one compartment, such as commercial fish, for restoration after it was contaminated, other compartments such as sediments or prey species could still recontaminate the fish. In order to benefit ourselves, we

must take care of the ecosystem in its entirety. This approach is gaining momentum in international environmental circles and changing the way in which the NWRI conducts aquatic research in the Great Lakes.

One prerequisite for an ecosystem approach is a means to evaluate the state of health of the ecosystem. Dr. Trefor Reynoldson, Lakes Research Branch, co-chairs a binational working group developing ecosystem objectives, indicators and measures for Lake Ontario. The working group, operating under the direction of the Binational Objectives Development Committee, is charged by the 1987 Protocol to the *Great Lakes Water Quality Agreement (GLWQA)* to produce a set of biological indicators which can be used to measure the health of the Lake Ontario ecosystem and progress towards the ecological objectives. The group bases its work on the premise that the surest indication of a healthy ecosystem is the presence of sustainable, self-reproducing biota.

The multi-agency group is composed of both Canadians and Americans working toward the common goal of a healthy, self-sustaining ecosystem. The group is broken up into the following six sub-groups, each developing biological indicators, means of measurement and targets for different components of the ecosystem:

BENTHOS

The benthic invertebrates subgroup, led by Janice Smith, Rivers



Research Branch, is examining ways to measure the health of benthic communities. These bottom dwelling organisms form an important link between sediments and the water.

PELAGIC COMMUNITIES

Likewise, the pelagic sub-group is investigating the fish and other planktonic communities which link the food web and habitat components of the ecosystem.

WILDLIFE

This sub-group looks at wildlife which rely on the Great Lakes for food, based on the assumption that what is contained in the water can also affect terrestrial organisms.

HABITAT

The habitat sub-group is defining requirements of healthy habitats for fish and wildlife, with the understanding that self-sustaining biological communities are only possible by preserving sufficient quantity and quality of habitat. Habitat loss and degradation through development of the shoreline or diminishing wetlands is one of the greatest threats to fish and wildlife populations in the Great Lakes Basin.

HUMAN HEALTH

The human health sub-group addresses concerns such as levels of contaminants and disease-causing microorganisms, and numerous aesthetic factors which affect human health and well-being.

STEWARDSHIP

The stewardship sub-group measures changes in attitudes and awareness of the role of humanity in the ecosystem, which includes acceptance of our responsibilities as caretakers of the environment.

Taken together, these sub-groups provide a comprehensive view of the health of the entire ecosystem, one which acknowledges the complex connections between land, air, water, plants and animals. Public opinion is also taken into account and was instrumental in establishing the scope of the project.

The Evolution Of A Philosophy

The concept of an ecosystem approach evolved over the past three

decades. Born as a philosophical movement in the 1960s, the approach gained prominence following enactment of the 1978 GLWQA between Canada and the United States. The prior agreement, signed in 1972, promoted restoration of water quality in the Great Lakes based largely on a specific chemical approach. Although this approach was effective in reducing "end of pipe" emissions of nutrients, it was unequal to the task of solving all the numerous, complex problems associated with Great Lakes pollution. The 1978 and 1987 revisions to the Agreement recognized this limitation and require development of both ecosystem and chemical specific objectives.

The ecosystem approach will have an increasingly pronounced effect on Great Lakes research as the concept continues to evolve.

In 1985, the International Joint Commission (IJC) and the Great Lakes Fishery Commission jointly published *A Conceptual Approach for the Application of Biological Indicators of Ecosystem Quality in the Great Lakes Basin* which offered guidelines for selecting ecosystem objectives and led to the inclusion of two ecosystem objectives for Lake Superior into the GLWQA. The indicators of a healthy Lake Superior ecosystem were defined as stable and self-reproducing populations of lake trout and the amphipod *Pontoporeia hoyi*. Dr. Reynoldson participated in another IJC effort which identified populations of mayfly (*Hexagenia limbata*) and walleye as suitable indicators for more productive waters such as western Lake Erie and Saginaw Bay.

The 1987 Protocol to the GLWQA specified that development of ecosystem objectives is a direct responsibility of the governments of Canada and the United States. From this arose the Binational Objectives Development Committee which advanced the concept of an

ecosystem approach to its current state.

The ecosystem approach will have an increasingly pronounced effect on Great Lakes research as the concept continues to evolve. The view of the Great Lakes as a highly integrated ecosystem will encourage partnerships with other research disciplines. The program in the Great Lakes Basin also represents one of the most formal approaches to ecosystem objectives development in the world and is expected to assist in development of the ecosystem approach to environmental management throughout Canada.

Dr. Reynoldson has lectured extensively on the topic, both in Canada and internationally. The expertise and knowledge developed in the Great Lakes Basin can be used as a template for ecosystem objectives development around the world.

Contact

Dr. Trefor Reynoldson

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New technique to combat reduced chemicals in sediments

Reduced chemicals, such as hydrogen sulfide, contribute to the toxicity of some Areas of Concern. Dr. Tom Murphy, Lakes Research Branch, is experimenting with a new technique that may be useful for treating sites with high concentrations of reduced chemicals, such as Hamilton Harbour and the St. Marys River.

The new technique injects oxidants into the sediments using equipment which resembles a long rake. This equipment is lowered off the end of a boat and pulled across the bottom sediments while injecting the chemicals, such as ferric chloride or calcium nitrate, into the sediments. These oxidants convert reduced chemicals into compounds which are less harmful to aquatic organisms.

Two pilot-scale ferric chloride treatments were completed on the St. Marys River during July and October. The river sediments near Sault Ste. Marie are in many ways similar to the contaminated sediments of Hamilton Harbour since both sites have received discharges from the steel industry.

The pilot-scale treatment significantly reduced the acute toxicity at the St. Marys site. Donald Marles, chairman of the St. Marys River Bilateral Public Ad-

visory Committee, says he is pleased by the success of the project. "We are encouraged by the recent studies initiated on the St. Marys River aimed towards developing technologies and methodologies for neutralizing in-place toxic sediments," says Marles.

Recently, Dr. Murphy completed a pilot-scale treatment of Hamilton Harbour sediments. Chemical tests to analyze the overall effect of the ferric chloride treatment on these sediments are being conducted.

A second oxidant, calcium nitrate, is being investigated in laboratory studies. Calcium nitrate shows great potential since it is a much more powerful oxidant than ferric chloride and less corrosive to the application equipment. Furthermore, oxidation by calcium nitrate enhances biodegradation of some aromatic contaminants, such as naphthalene, a byproduct of the coking process used in steelmaking. When oxygen is present, certain naturally occurring bacteria



photo by Dr. Tom Murphy

Dr. Tom Murphy's field crew inject reduced sediments in the St. Marys River with ferric chloride.

produce oxidases which can cleave aromatic rings, thus inactivating them or breaking them down into smaller compounds. Dr. Murphy is currently analyzing the effectiveness of calcium nitrate to enhance biodegradation of the 16 priority polynuclear aromatic hydrocarbons (PAHs). Although ferric chloride enhances biodegradation to a lesser extent, its inactivation of hydrogen sulfide is still potentially useful.

If the Hamilton Harbour trials are successful, the technique could be used to pretreat the PAH contaminated sediments located in one of the Harbour's "hotspots".

Contact

Dr. Tom Murphy

THE SPEED OF WATER

The speed and force of waves constantly challenge the stability of coastal and offshore structures. In designing structures to meet this challenge, engineers use mathematical wave models to predict the nature and extent of the forces. However, many models fall short due to the limitations of applying standard linear theory to the complex, erratic wave patterns found under natural wind and wave conditions.

Dr. Mark Donelan, Research and Applications Branch, in collaboration with Dr. Jay Doering and Francois Anctil have made an advance

in this area by developing a method to calculate the velocity field beneath irregular waves in a theoretically consistent manner.

Irregular waves generated in a laboratory are designed to simulate naturally occurring waves. The scientists developed a mathematical model to accurately predict the local velocities within these waves and compared their predictions to irregular waves generated in the wind-wave flume at NWRI.

The calculations can also be used to predict mean wave drift. This information may be used to deduce

the drift of pollutants and other flotsam.

A computerized version of the method suitable for use with a personal computer is available from Dr. Donelan.

Contact

Dr. Mark Donelan

Reference

Donelan, M.A., Anctil, F. and J.C. Doering. 1991. A simple method for calculating the velocity field beneath irregular waves. NWRI Contribution 91-111 (also in *Coastal Engineering*, in press).

WORKING TOGETHER

Ecotoxicology of coplanar PCBs

Dr. Chris Metcalfe,

Environmental and Resource Studies Program, Trent University

Dr. Doug Haffner and Dr. Michael Dufresne,

Department of Biology, University of Windsor

Dr. Frank Gobas,

Department of Natural Resource Management,

Simon Fraser University

For over 25 years, polychlorinated biphenyls (PCBs) have been known to contaminate the Great Lakes ecosystem. PCBs are a complex mixture of chlorinated biphenyl compounds, or "PCB congeners", which are recognized chemical contaminants present in fish-eating birds, fish, plankton, sediment and water of the Great Lakes. Until recently, all PCBs were assumed to be of equal toxicity, and monitoring efforts in the Great Lakes concentrated on determining levels of total PCBs.

Scientists now recognize that many PCB congeners are relatively harmless. In fact, only a small group, perhaps as few as three, may be toxic to biota. The toxic congeners are known as "coplanar PCBs". This has implications for the monitoring of PCBs in the Great Lakes. It is known that the levels of total PCBs in all of the lakes have declined throughout the 1980s, but it is not known whether coplanar PCBs have followed the same trend.

Drs. Chris Metcalfe, Doug Haffner, Michael Dufresne and Frank Gobas are analyzing trends of coplanar PCBs in Great Lakes food chains. Part of this study involves analyzing samples of Lake Ontario lake trout archived throughout the 1970s and 1980s. The scientists will also determine whether coplanar PCBs are magnified to a greater extent through food chains than non-toxic PCB congeners.

The scientists are also examining the toxicology of coplanar PCBs in native species of the Great Lakes. This includes determining if coplanar PCBs are embryotoxic, or whether they impair the overall reproductive success of Great Lakes fish and birds through other means.

Results of this GLURF project will contribute to an overall understanding of whether the existing GLWQA objective for total PCBs in fish tissue truly protects the Great Lakes ecosystem.

GLURF participants to present at IAGLR '92

Many of the GLURF recipients will be presenting their results at the 35th annual conference of the International Association for Great Lakes Research (IAGLR). The conference will be held May 31 to June 4, 1992, at the University of Waterloo. The purpose of the conference is to exchange information on all aspects of research related to large lakes of the world and to the human societies surrounding them.

Papers on all aspects of Great Lakes research are invited. Abstracts are required for both poster sessions and contributed papers. All abstracts must be received by Jan. 31, 1992.

For further information, please contact Dr. Marie Sanderson, Department of Geography, University of Waterloo, Waterloo, Ontario, N2L 3G1; or phone (519) 885-1211 (ext. 6962 or 2433).

As the 1991-92 selection process for the Great Lakes Under-
Fund (GLURF) begins, it is
the recipients of last year's GLURF

The GLURF was created to promote research that
will assist Canada in fulfilling its obligations under the
Quality Agreement (GLWQA). The GLURF encourages
partnerships between universities and government agencies
together multidisciplinary teams to address
knowledge gaps in Great Lakes research.

Due to space considerations, only a few
GLURF projects in this issue. The GLURF
studies provide terrific examples of
partnerships within the broader Great Lakes

Toxic chemicals in the Great Lakes

Dr. Don Mackay,

Institute for Environmental Studies, University of Toronto

Dr. Don Mackay, in partnership with the
Inland Waters Directorate (Ontario Ministry of the Environment), is developing
models which will be useful to both scientists and managers in the
Lakes Basin.

The research addresses opposing views on the use of computer models.
Many scientists and engineers with a background in toxicology are
convinced that the programs to predict the fate of chemicals in the
ecosystem will be greatly assisted by the use of computer models in
describing the fate of these chemicals. However, some scientists feel
that computer models are too expensive and may contain hidden
complications.

Basic chemical research in the Great Lakes

Dr. Victor Snieckus,

Department of Chemistry, University of Waterloo

A proactive approach to water quality management requires the
elimination of known pollutants and the development of new
compounds in the environment. Polycyclic aromatic hydrocarbons (PAHs) are a
complex group of pollutants, many of which are carcinogenic. It is
difficult to detect and monitor PAHs in the environment without
reference standards. This recognition of the need for basic chemical
research forms the basis for this GLURF project.

R OUR ENVIRONMENT

Great Lakes University Research
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Mass balances Lakes

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requires the use of high-purity PAH
archers involved in Great Lakes Basin

Continued on p. 6

Socio-economic consequences of regulations for toxic chemical abatement

Dr. Mark Sproule-Jones,

Department of Political Science, McMaster University

The growing awareness of toxic chemicals and their effects is pronounced in the Great Lakes region, and in particular the Areas of Concern. Funded by GLURF, Dr. Mark Sproule-Jones is evaluating the design of policy instruments (i.e. the laws, regulations and programs of several governments) necessary for toxic chemical abatement.

The aim of the study is to disentangle those regulations that are unenforced and unenforceable ("rules-in-form"), from those that are or could be used to tackle the toxic pollution problem ("rules-in-use"). Dr. Sproule-Jones will develop evaluation criteria, based on an ecosystem approach, that can be used to appraise the "rules in use". This approach parallels ongoing work by Great Lakes researchers on ecosystem indicators.

In forthcoming months, the "rules-in-use" will be identified in the case of Hamilton Harbour, one of the Areas of Concern. This will be accomplished through collaboration with stakeholders, which include representatives of federal and provincial governments, private sector and interest group organizations engaged in the Hamilton Harbour Remedial Action Plan. Finally, the assessment criteria will be used to evaluate the strengths, weaknesses, gaps and redundancies inherent in the "rules-in-use".

The project thus marries the strengths of social and natural science disciplines to examine the reasons for the enforceability of regulations and develop an ecosystem method for assessing the impact of regulations on the water quality environment.

Predicting the toxicities of narcotic contaminants

Dr. Rob Peters,

Department of Biology, McGill University

The cost to measure the individual effects of the ever-increasing number of chemicals on the numerous species of the Great Lakes ecosystem makes the task not just impractical, but impossible. A more efficient approach would be to use our knowledge about the effects of a few chemical species on a similarly small number of biological species to synthesize general theories about environmental contamination. Under the GLURF, Dr. Rob Peters is testing such a theory using narcotics as a focus.

Narcotics are a large family of organic compounds which includes alcohols, ethers, ketones, benzenes and halogenated aliphatic hydrocarbons. Narcotics disrupt the general functioning of an organism, possibly by causing intracellular membranes to swell and distort until they no longer work. Dr. Lynn McCarty hypothesized that narcotic inhibition does not reflect the properties of each chemical. Instead, he proposed that organisms cease to function when the internal concentrations of narcotic reached a certain threshold.

Continued on p. 6

Chain Lake residents take action

Residents living near Chain Lake, British Columbia have decided that they are going to rid the lake of excess algae — even if they have to raise their own taxes to do it!

The geology around Chain Lake is rich in phosphorus-containing rocks. The phosphorus is leached from the rock by groundwater which enters the lake and stimulates algal growth. In the past, the algal growth has been extensive, depriving lake organisms of oxygen and causing fish kills.

Dr. Tom Murphy, Lakes Research Branch, has investigated low-cost restoration options for Chain Lake since the mid-1980s. He has recommended a drainage system to siphon off phosphorus-rich bottom water during the summer months and is providing technical advice for installation. Drawing off the water before it can mix with the surface water would reduce one source of nutrients for algal growth and lead to a subsequent increase in oxygen.

The inexpensive procedure will cost an estimated \$60,000. At a meeting last September, the public council petitioned to raise their taxes to cover \$10,000 of the overall amount. Applications for federal and provincial grants to cover the remaining expenses are being prepared by Dr. Greg Lawrence, University of British Columbia and the local residents.

Contact

Dr. Tom Murphy

WORKING TOGETHER FOR OUR ENVIRONMENT

Continued from p. 5 & 6

Toxic chemical mass balances in the Great Lakes

Dr. Mackay's team is attempting to bridge the gap between these two viewpoints. The models they create will be simple and reliable enough to be useful in formulating remedial action strategies by regulatory agencies, but will retain sufficient detail and rigour to be accepted by the research community. They will provide a complete mass balance "accounting" of the fate of specific chemicals and can be used to deduce concentrations in water, sediments and various biota ranging from benthos and phytoplankton to salmonids and fish-eating birds.

The models can currently be validated for chemicals such as PCBs and lead for which there are nearly complete data on sources and concentrations throughout the ecosystem. This will lend confidence to the application of the models to other chemicals for which there are only fragmentary data.

It is hoped that this project will permit effective use of mass balance models by the Great Lakes community and help in the formulation of effective, justifiable strategies to achieve the GLWQA aim of "virtually eliminating" toxic substances from our ecosystem.

Basic chemistry in service of environment quality

Using efficient synthetic methods recently established in his laboratories at Waterloo, Dr. Snieckus and his students are preparing a number of PAHs which are proven contaminants. High Pressure Liquid Chromatography (HPLC) and Gas Chromatography-Mass Spectrometry (GC-MS) are used to obtain and ascertain high purity standards. These standards are then submitted to scientists engaged in PAH detection and analysis for unequivocal verifica-

tion of PAHs in samples obtained from the Great Lakes Basin.

Through collaboration with researchers at NWRI, Dr. Snieckus has been able to concentrate his efforts on those PAH reference standards most urgently required. These new standards will form part of an ongoing collection of reference materials being accumulated by Dr. Snieckus and his associates in anticipation of new toxic pollutants.

Predicting the toxicities of narcotic contaminants

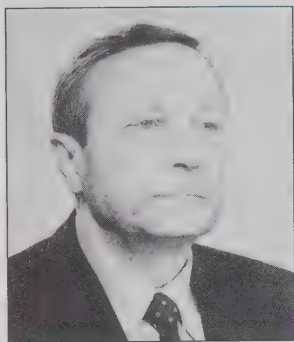
To test this hypothesis, Dr. Peters will expose water fleas to lethal concentrations of different organic narcotics. Radioactively labelled narcotics will allow the scientists to directly measure very low concentrations of each compound, even the concentration necessary to immobilize a single water flea. If the internal concentrations at death for different compounds are no more variable than those observed in replicated trials with a single compound, then the theory will be supported.

Once the lethal internal concentration of narcotics is determined, the predictive power of the theory can be tested. Internal lethal con-

centrations can be established for different species, narcotics and environments. If the hypothesis holds, similar total internal concentrations of narcotics should result in death in all experimental variations.

Future research could then concentrate on factors controlling the rate and extent of narcotic uptake and on establishing estimates of internal lethal concentrations for other chemical families with characteristic modes of action. In this way, we will be able to construct models that reduce the need for toxicity testing and accurately predict the impact of a given dose of contaminants in nature.

1991 Vollenweider lecture



Dr. Kirill Ya. Kondratyev

The 1991 R.A. Vollenweider Lectureship in Aquatic Sciences was awarded to Dr. Kirill Ya. Kondratyev. Dr. Kondratyev is an internationally recognized expert in atmospheric physics and space ecology. He currently acts as Academician and Councillor at the Institute of Lake Research in Leningrad, under the USSR Academy of Sciences.

Dr. Kondratyev's lecture, entitled "Limnology and Global Change", was presented at the Canada Centre for Inland Waters on October 4 and focussed on the use of lake ecosystems as sensitive indicators of past and present global change. He also held informal discussions with Institute scientists throughout his four-day visit and lectured at several nearby universities and the Atmospheric Environment Service in Downsview.

Water pollution research symposium

The Twenty-Seventh Central Canadian Symposium on Water Pollution Research will be hosted by the Wastewater Technology Centre and the NWRI on February 12, 1992, at the Canada Centre for Inland Waters.

The themes of this annual symposium are: Water Pollution Control Technology, and the Impact of Pollutants on Aquatic Ecosystems. The title of this year's special session is "Management of Urban Lakes".

The objectives of the symposium are to stimulate discussion on

recent Canadian research projects and facilitate information exchange between governments, industry and universities. The symposium also provides an excellent opportunity for participants to display their research accomplishments at the poster session.

For more information contact Tracey Batt, Canadian Association on Water Pollution Research and Control, c/o The Wastewater Technology Centre, 867 Lakeshore Road, P.O. Box 5068, Burlington, Ontario, L7R 4L7, tel: (416) 336-4598.

ECOSYSTEM
HEALTH



Open House 1992

Come and visit!

Learn more about NWRI research on water-related environmental issues during the 1992 Open House at the Canada Centre for Inland Waters!

The theme of the 1992 Open House is **Ecosystem Health: It's Everybody's Business**. This focusses on the need for government, industry and the public to work together in order to repair and protect our environment. Held to coincide with Environment Week, the Open House promises to be one of the largest environment-related events during that week.

Bring the family! June 6 - 7 is reserved for families and the displays will appeal to all ages.

For more information, phone: (416) 336-4973

Reaching a wider audience

If you are looking for a little "light reading", you might not want to pick up *The Role of Particulate Matter in the Transport and Fate of Pollutants*. The publication, released this year by the Chinese Academy of Sciences, is based on the proceedings of a 1983 conference held in Australia. Roughly half of the publication is allocated to presentations on toxic chemicals in lake ecosystems by Dr. Rod Allan, Director of Lakes Research Branch and sole keynote speaker at the conference. Published in Chinese, the proceedings may be a little out of reach of a strictly English-speaking audience, but they serve to introduce Dr. Allan's ideas to a very extensive Chinese readership.

Contact

Dr. Rod Allan

Lead-210 dating service now available

The Research and Applications Branch has recently begun offering lead-210 dating as one of their technical services. Lead-210 dating is a valuable tool in both research and routine analysis for environmental assessment and monitoring.

Lead-210 is a decay product of atmospheric radon-222. Rain carries some of the lead-210 to lakes where it becomes adsorbed to particles of clay and organic matter settling out of the water column. The adsorbed lead-210 provides a useful means for determining the sedimentation rate and chronological age of the sediments.

Contact

George Duncan



NWRI *Digest* is the public newsletter of the National Water Research Institute, Canada's largest freshwater research establishment. The Institute conducts a comprehensive program of research and development in the aquatic sciences which it undertakes in partnership with water management agencies and water science communities in Canada and around the world. Our research creates knowledge and develops expertise on water quality issues important for sustainable water resource use and the preservation of freshwater ecosystems.

Suggestions, comments and further enquiries concerning NWRI *Digest* are welcomed. Articles may be reprinted upon permission from the editor. Please write to:

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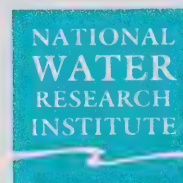
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THE NEWSLETTER OF THE NATIONAL WATER RESEARCH INSTITUTE

Scientists study UV impacts on aquatic ecosystems

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**Global
Watershed Atlas**

~ 4&5 ~

**LET'S RAP
Hamilton Harbour:
A success story**

~ 6 ~

**Remotely
monitoring
biological
productivity**

~ 6 ~

**1991-1992
GLURF recipients**

Sun, surf and sand -- that's what summer was all about. But recently, the sunlight consists of a higher proportion of ultraviolet (UV) radiation due to thinning of the stratospheric ozone layer. We have all heard health warnings urging us to avoid excess exposure to sunlight, but what about aquatic animals and plants that can't escape the sun's damaging rays?

Under the Green Plan's Ozone Depletion initiative, NWRI scientists are studying the response of aquatic ecosystems to increased UV radiation. Dr. David Lean, Lakes Research Branch, co-ordinates a research program that investigates the physical, chemical and biological effects of increased UV exposure on inland rivers and lakes. The program involves partnerships with the National Hydrology Research Institute (NHRI) and several universities.

Understanding light

Before you can understand the effects of UV light on aquatic ecosystems, you must first understand what happens to UV rays as they travel through natural waters. Dr. Bob Bukata

and John Jerome, Rivers Research Branch are studying the factors that affect the scattering and absorption and UV-B radiation in aquatic systems.

The study consists of two components. In the laboratory, Dr. Bukata and Jerome are examining how UV-B radiation travels across the air/water interface. The wavelength of UV-B ranges from 280 - 320 nm, while UV-A ranges from 320 - 400 nm. Although there is relatively more UV-A radiation striking the earth, it is the UV-B part of the spectrum that causes severe sunburn. After calculating the amount of UV light entering the system, scientists will attempt to define the *photon budget*; that is, how much each component of aquatic ecosystems absorb and scatter light. There are many components to analyze, but they are focussing their studies on four believed to be most actively involved in the propagation of UV-B radiation through natural waters: phytoplankton, dissolved organic carbon, suspended sediments, and pure water. The laboratory study aims to determine the amount of UV-



B absorption and scattering that can be ascribed to an unit concentration of each aquatic component.

The characteristics of Canadian waters vary dramatically according to location and season and the inorganic and organic composition of the water body will largely determine the impact of changes in UV-B light levels. The second component involves developing computer models which can simulate the propagation of the UV-B spectrum through these waters. Since it is difficult to accurately measure the low levels of UV-B encountered in natural waters, such computer modelling will be very useful in relating measurements of above surface UV-B radiation to the optical processes occurring beneath the surface. This will facilitate understanding of the impacts of changes in UV-B on a variety of aquatic ecosystems.

Radical studies

UV light is powerful enough to trigger chemical reactions that can alter the way an aquatic ecosystem functions. Dr. Lean and Dr. Jerome Nriagu, Lakes Research Branch, working with a team of graduate students and professors at Trent, York and Florida International University, are trying to predict ecosystem response to influence of UV light in lakes and wetlands.

One way in which UV radiation can affect ecosystems is by stimulating production of oxygen radicals. In the presence of humic substances (a complex group of chemicals which lend an amber colour to lakes and ponds) UV light can transform oxygen into radicals, such as singlet oxygen ($^1\text{O}_2$). Singlet oxygen has a very short lifetime in water but may be toxic to

organisms and reacts readily with various naturally occurring or artificial compounds. Another radical produced is the transient superoxide ion (O_2^-) which quickly converts into hydrogen peroxide (H_2O_2).

Oxygen radicals can spur chemical reactions with metals and organic compounds. In fact, some levels of UV can cause the photochemical formation of highly reactive chemicals which are toxic to biota, even though the original chemicals were at "safe" concentrations. For instance, hydrogen peroxide has been known to convert relatively benign trivalent chromium to hexavalent chromium, which is much more toxic and carcinogenic. Industrial systems discharge both trivalent and hexavalent chromium but now hexavalent chromium is found to be the most dominant form in the Great Lakes. Dr. Nriagu is studying this phenomenon and its effects on biota.

In theory, the impact of these reactions on aquatic ecosystems should be greater in northern lakes and wetlands; presumably because these ecosystems are not adapted to high levels of UV radiation. Based on his previous work in this area, Dr. Lean predicts that the greatest impact of oxygen stress will be felt in shallow, poorly buffered, coloured ponds at latitudes where UV light levels are substantial, the days are long, and the cold weather inhibits the growth of bacteria which break down hydrogen peroxide.

Dr. Lean and his team will be studying this effect at Atmospheric Environment Service monitoring stations on Ellesmere Island, Resolute Bay, and Cornwallis Island (NWT), at Churchill (Manitoba), and in

temperate systems within Ontario. While the hourly UV-B flux rate is lower at high latitudes, the daily rates are quite high during the summer. Above the tree line, values for dissolved organic carbon are generally lower. This results in greater UV-B penetration. In addition, work will be conducted in collaboration with Florida International University on subtropical environments located in the Everglades National Park/Biosphere Reserve.

Much of the team's current work is occurring at the laboratories of the Environmental Science Centre at Trent University. They have developed field techniques to be evaluated in the Arctic in the future.

Adapting to a hostile environment

Dr. Max Bothwell, NHRI, is working as a team member with professors from the University of British Columbia and the University of Saskatchewan to explore the consequences of increased UV on riverine ecosystems and evaluating the ability of these systems to adapt.

The project involves investigating the biological response of UV light in natural flowing waters. Dr. Bothwell will then go on to study the impact of UV light on the microbiology of natural flowing waters by analyzing the adaptive mechanisms of periphytic diatoms. What affects these microorganisms at the base of the riverine food chain is likely to influence the entire community. However, different species of diatoms will vary in their sensitivities to UV light. Dr. Bothwell will be comparing the effects of UV light on different species of diatoms to see how this will change the overall

structure of the periphytic community.

Understanding future problems

Canada continues to be a frontrunner in international efforts to decrease the levels of ozone-depleting chemicals in the atmosphere. The *Montreal Protocol*, signed in 1987 and revised in 1990, took major strides in reducing the levels of chlorofluorocarbons (CFCs), compounds believed to contribute substantially to destruction of the ozone layer.

Unfortunately, ozone-depleting chemicals tend to persist in the atmosphere. This means even if the participating nations adhere to the terms of the *Montreal Protocol*, we may not see significant improvements until years later. Understanding the effects of potential future increases in UV-B on our aquatic ecosystems is of paramount importance if we are to maintain the beneficial uses of our lakes and rivers.

Contact:

Dr. David Lean

Managing urban lakes

by Dr. Jan Barica

By the end of this century, it is predicted that one half of the earth's population will live in urban centres. This trend calls for a hard look at the relationships between cities and the lake and river basins they occupy. Cities are too often treated as point sources of pollutants, even though their size and developmental influence throughout the basin provide many mechanisms for interaction. Cities, in fact, are ecosystems in their own right.

A special symposium on management of urban lakes was convened at NWRI to consider this issue. It was held under the auspices of the 27th Central Canadian Symposium on Water Pollution Research and Control on February 12, and hosted jointly by NWRI and the

Wastewater Technology Centre. The symposium centred on two representative urban lake systems: the Berlin reservoir system in Germany and Hamilton Harbour, Ontario. In addition, case studies from Brazil, Poland, Southern Germany, Quebec, British Columbia, Alberta and Ontario were discussed.

Under Canada-Germany scientific cooperation programs, separate meetings were held with the Ontario Ministry of the Environment on phosphorus removal technologies in both countries and on water cycle management in urban areas.

The proceedings of the symposium will be published in the *Water Pollution Research Journal of Canada*.

Global watershed atlas

Andy Fraser, International Programmes Group, and his colleagues recently completed development of a global freshwater "electronic atlas".

The atlas contains maps and information on 82 major watersheds around the globe and can be viewed on a global, continental or watershed level. It also outlines major environmental issues for each of the watersheds and retrieves statistical analyses and trends

on over 25 water quality parameters, including major ions, electrical conductivity and nutrient concentrations. This initial version of the program stores over 1300 computerized images. Further refinements and additions to the database are planned.

The atlas uses data from the Global Environment Monitoring System for Freshwater (GEMS/WATER) and was produced under contract with the United Nations Environment

Programme (UNEP). The RAISON (Regional Analysis by Intelligent Systems ON a Microcomputer) expert system, created at NWRI, was used to develop the atlas.

Fraser presented the atlas at the United Nations International Conference on Water and the Environment (ICWE) in Dublin, Ireland during January.

Contact:

Andy Fraser

In 1875, a reporter for *The Hamilton Spectator* described Hamilton Harbour as "Calm and beautiful; clothed with lazy sails and surrounded by rich and hazy hills, it presents a scene which, to the lovers of the beautiful, is unexcelled."

At that time, the Harbour (also known as Burlington Bay) was a focal point for the Hamilton community, as well as an unspoiled habitat for wildlife. Vast marshes provided a home for frogs, fish and birds of all kinds. What's more, the Harbour was a natural playground for sailing, swimming and fishing. In fact, fishing was a major industry in the Harbour.

Since then, human activities have made their mark on the Harbour. The amount of sewage discharged into this small bay escalated as the populations of Hamilton, Burlington, Stoney Creek, Dundas, Ancaster and Waterdown continued to swell, eventually causing the first beach closures during the 1940s. The wetlands were filled in to make way for expanding industry; the same industries which infused the Harbour with toxic chemicals. The Harbour had become a huge wastewater lagoon that processed, digested and temporarily stored all of the urban and industrial wastes from the entire watershed. Municipalities and industry have already begun to reduce their sewage and toxic chemical discharges. This is just one step in a community-wide effort to clean up the Harbour.

In the 1970s, Hamilton Harbour was identified as an Area of Concern by the International Joint Commission. In 1986, the



Water clarity in some areas of the Harbour is poor due to high levels of algae and suspended sediments near the shoreline.

official Hamilton Harbour Remedial Action Plan (RAP) was launched to revive the Harbour as a dynamic recreational and natural resource. The RAP committee is composed of public, industry and government stakeholders with direct interests in the Harbour. The process, co-ordinated by Dr. Keith Rodgers of NWRI, entered Stage Two in January -- the recommendation of remedial actions which has been reviewed by the general public and interested agencies around the area.

The recommendations confront past and present pollution problems, and identify ways to maintain a restored Harbour. The two major historic impediments to the clean-up are contaminated sediments and habitat loss. Thirty to 40 cm of organic and metal-contaminated

clay and silt line the Harbour floor. Toxic ("benthic") organisms and occasionally any significant reduction in toxic chemicals must be detoxified or removed and treated some to be "useless swampland" habitat.

Yet perhaps one of the biggest challenges in the clean-up. Burlington is catching the eye of the population around the Harbour grows to be developed to accommodate increased strict control over bacterial, ammonia, and other pollutants in the Harbour.

A Team Effort

The Stage Two RAP report represents a joint effort by government. NWRI scientists are helping the government and non-government experts to provide technical information and advice on the progress of the projects:

Defining the nature, extent and origins of contaminant distribution in Harbour: The toxicity and composition of the coal tar to remove and clean the coal tar. The coal tar originated historically from coke ovens.

Determining the effects of contaminants on benthic invertebrates: Benthic invertebrates were sampled at 13 sites along a transect of the Harbour. Species diversity decreased with increasing contamination, the size of the population suggests that both physical and chemical factors, low oxygen levels, sediment type and chemical contaminants are responsible for the distribution of benthic invertebrates.

Testing methods to detoxify sediments: A method was developed that treats reduced chemical contaminants by injecting oxidants such as ferric chloride and nitrate. The oxidants convert reduced compounds which are less toxic to aquatics and enhance bacterial degradation of contaminants. The technique may be used to pretreat highly contaminated areas prior to dredging.

Predicting the effect of changes in nutrient loading on sewage treatment plants (STPs) on algal water clarity: Water clarity was sampled at 13 sites in 1990. The results showed a significant increase in phosphorus coming from the STPs, which is necessary to cause large reductions in water clarity.

RAP

A success story

nts are toxic to many bottom-dwelling (or ate the water column. In order to achieve o the Harbour ecosystem, these sediments rmore, infilling of what was considered by arge areas of important fish and wildlife

ntain the status of the Harbour following ater Toronto area expansion which will see er the next 20 years. New technology must f sewage while still maintaining the same olids and phosphorus discharges into the

ined efforts of the public, industry and ed in the RAP, working alongside other ide the RAP Stakeholders with pertinent ssues in the Harbour. Here are just a few

bottom sediments: A detailed map of toxic as prepared. The research results of the our were used in planning pilot-scale work ene concentrations suggest that the coal eams.

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levels also remained relatively high. Both algae and ammonia are implicated in the low oxygen levels found within the Harbour. This study helps direct further refinements to the STPs.

Refining estimates of water circulation: Water circulation within Hamilton Harbour and the exchange of water between the Harbour and Lake Ontario is a very complex process which affects the fate of contaminants. Water enters the Harbour from precipitation, creeks, drains, sewer outfalls and groundwater seepage. Water is also exchanged with Lake Ontario via the ship canal due to changing water levels and the outflow of warm Harbour water during the summer. Understanding and quantifying these circulation patterns lends insight into contaminant flows and helps direct remedial measures.

Quantifying the transport of contaminants from the Harbour into Lake Ontario: One environmental concern is whether large quantities of Hamilton Harbour contaminants flow outward into Lake Ontario. NWRI researchers found that the loading of PCBs and polynuclear aromatic hydrocarbons (PAHs) from Hamilton Harbour into Lake Ontario was 30 and 300 times lower than loads from the Niagara River.

But despite NWRI's technical input, the RAP document remains a community-based project, not a government endeavour. Dr. Rodgers says he is pleased by the general public's ability to understand and provide valuable suggestions on difficult technical concepts; reaffirming the value of public input in the RAP planning stages. All the public input has now been compiled and assimilated into the Stage Two Report. The Stakeholders Group have submitted this set of recommendations to the federal and Ontario governments and the final report is due for release this fall.

Contact

Dr. Keith Rodgers

Reference:

Remedial Action Plan for Hamilton Harbour. Stage Two draft report, 1991.



Hamilton Historical Society

Aerial photo of Cootes Paradise during the 1920s. Since this picture was taken, over 85 per cent of the wetlands have disappeared due to high water levels, the destructive activities of carp and poor water quality (i.e. excess nutrients and suspended sediments).

Remotely monitoring aquatic productivity

Rivers Research Branch scientists Dr. Bob Bukata and John Jerome recently received the 1991 - 1992 Chandler-Misener Award, given annually by the International Association of Great Lakes Research for the best paper to appear in the organization's publication, The Journal of Great Lakes Research. The award was given for two papers dealing with remote sensing of biological productivity in inland waters and its applications for satellite monitoring of global change.

Keeping track of changes in aquatic biological productivity is an important aspect of international programs to monitor global change. For nearly two decades, oceanic productivity has been remotely monitored with considerable success using satellite spectral data. Algorithms relate the amount of visible light reflected at specific wavelengths from the earth's surface to the amount of chlorophyll in the upper water layer. This gives an indirect measure of phytoplankton biomass and biological primary productivity.

But equally as important and much more difficult to measure is the productivity of inland waters. In an optical sense, these waters are far more complex than oceanic bodies. Due to nearby land masses, the water is dominated by various inorganic and organic substances which compete with chlorophyll for sunlight at specific wavelengths. Consequently, the optical spectrum reflected from the water represents a sum total of all these components. Extracting the contribution of chlorophyll from this elaborate spectrum has proven to be a complex undertaking.

Dr. Bukata and Jerome, along with Ed Bruton, Rivers Research Branch, developed a model which estimates chlorophyll-a, suspended mineral and dissolved organic carbon concentrations, based on a single

remote measurement of water colour at those wavelengths presently utilized in satellite monitoring.

The model was used successfully to extract the organic and inorganic components in Lake Ontario from remote sensing data. In collaboration with Russian scientists Drs. Kirill Kondratyev and Dimitry Pozdnyakov, this method was used to compare Lake Ontario parameters with Lake Ladoga in northern Europe. The two lakes were found to be quite different with regard to inorganic content, but optically comparable for chlorophyll-bearing biota.

The scientists have also been invited to participate in NASA's BOREAS (Boreal Ecosystem - Atmosphere Study) and SeaWiFS (Sea-viewing Wide-Field-of-view Sensor) projects. BOREAS is a joint Canada/U.S. program which aims to improve our understanding of the interactions between the boreal forest biome and the atmosphere in order to clarify its roles in global climatic change. SeaWiFS is concerned with marine phytoplankton processes as they relate to the impacts of climate change on aquatic carbon, sulphur and nitrogen cycles. The work of these scientists will also help us fulfil our Green Plan commitments, including explorations into the potential effects of global change on our water resources.

References:

Bukata, R.P., Jerome, J.H., Kondratyev, K.Y. and D.V. Pozdnyakov, 1991. Satellite monitoring of optically active components of inland waters: An essential input to regional climate change impact studies. *J. Great Lakes Res.* **17**(4): 470-478.

Bukata, R.P., Jerome, J.H., Kondratyev, K.Y. and D.V. Pozdnyakov, 1991. Estimation of organic and inorganic matter in inland waters: Optical cross sections of Lakes Ontario and Ladoga. *J. Great Lakes Res.* **17**(4): 461-469.

GLURF

Congratulations to this year's Great Lakes University Research Fund (GLURF) recipients! The following are the list of successful candidates: Dr. I. Tsanis (McMaster University), Dr. R. Thomas (University of Windsor), Dr. V. Sniekus (University of Waterloo), Dr. B. Sleep (University of Toronto), Dr. K. Howard (University of Toronto), Dr. W.G. Sprules (University of Toronto), Dr. W. Inniss (University of Waterloo), Dr. J. Lovett-Doust (University of Windsor), Dr. W.E. Watt (Queen's University), Dr. F. Gobas (Simon Fraser University) and Dr. C. Metcalfe (Trent University).

The next application deadline is October 2, 1992.

Contact Suzanne Ponton at (416) 336-4884 or fax (416) 336-6444.

in brief



Open House 1992 **Thanks for coming out!**

Close to 30,000 people from across Ontario visited the Canada Centre for Inland Waters during our Open House, June 4 - 7. Harry Savile, Research Support Branch, is seen here helping one of our younger visitors try on some diving equipment.

Held this year as part of Canada's Environment Week festivities, the Open House represented an opportunity for the public to learn more about scientific research on such water-related environmental issues as zebra mussels, toxic contaminants, acid rain, groundwater contamination, and many others. Our survey indicated that our visitors left with a better appreciation of our environment and an understanding that we must all work together to preserve and protect the health of our freshwater ecosystems.

Awards to NWRI scientists

Congratulations are extended to Dr. Jerome Nriagu, Lakes Research Branch, who has been elected a Fellow of the Royal Society of Canada. He was cited for his outstanding work in the geochemistry of sulphur and toxic trace metals in the environment.

Dr. Dave Lam, Dr. Bill Booty, Isaac Wong, and Andy Fraser of the International Programs Group have received the Departmental Citation of Excellence. The awards recognize the outstanding work of these scientists in developing the RAISON (Regional Analysis by Intelligent Systems ON a microcomputer) expert system.

A poster outlining one application of the LEAF (Laser-Excited Atomic Fluorescence) spectrophotometer recently received first prize for scientific content and graphic presentation at the 22nd International Roland W. Frei Memorial Symposium on Environmental Analytical Chemistry, held in Dortmund, Germany during June. The poster was based on the paper "Application of LEAFS to the Determination of Lead in Environmental Samples by Direct Analysis" by Dr. Ven Cheam, Joe Lechner and Dr. Ivan Sekerka, Research and Applications Branch, along with Roland Desrosiers, Research Support Branch.

***In-Situ* Bioremediation Symposium '92**

The 1992 Symposium on In-Situ Bioremediation will be held September 20 - 24 at Niagara-On-The-Lake, Ontario.

For more information, please contact

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NWRI *Digest* is the public newsletter of the National Water Research Institute, Canada's largest freshwater research establishment. The Institute conducts a comprehensive program of research and development in the aquatic sciences which it undertakes in partnership with water management agencies and water science communities in Canada and around the world. Our research creates knowledge and develops expertise on water quality issues important for sustainable water resource use and the preservation of freshwater ecosystems.

Suggestions, comments and further enquiries concerning NWRI *Digest* are welcomed. Articles may be reprinted upon permission from the editor. Please write to:

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THE NEWSLETTER OF THE NATIONAL WATER RESEARCH INSTITUTE

h i g h l i g h t s

4
Keeping the
kokanee
in
Kootenay Lake

4
AFTER THE
STORM
Managing urban
stormwater

5
Measuring ice jam
thickness

6
The impact of
waste tires on
aquatic
ecosystems

Clues to the past *Hamilton Harbour core reveals environmental history*

Locked beneath the surface of Hamilton Harbour, sediments undisturbed for thousands of years are providing us with environmental information that far predates human records.

Researchers in the Lakes Research Branch, working with scientists from the University of Waterloo, have analyzed two 8 m sediment cores retrieved from Hamilton Harbour during June 1991. Using clues from microscopic fossils and physical sediment properties, the scientists have pieced together the environmental changes that have occurred in the area over the last 7500 years.

Unlocking history

Over 11 000 years ago, the Hamilton Harbour area was covered by a large, deep glacial lake (Lake Iroquois) which eventually drained out through the deglaciated St. Lawrence valley. This relatively low-lying drainage outlet caused the water levels in Lake Ontario to drop almost 100 m below present levels and left the Harbour as dry land.

After the oldest sediments in the core were deposited, the water level in the main basin of Lake Ontario rose once again. This caused the streams flowing into western Lake Ontario to back up and created a marsh environment in the Hamilton Harbour area. Fossilized peat found near the oldest base of the core attests to a restricted marsh environment. Dr. John Coakley used radiocarbon dating of sediment organics (performed at the University of Waterloo) to link this marsh environment to a low-level stage in Lake Ontario which occurred between 5000 and 7000 years ago.

Dr. Denis Delorme studied fossilized ostracodes throughout the core to reveal the physical, climatic and chemical changes that occurred in the Harbour. The calcitic shells of these tiny organisms are preserved in the sediments and their specific species composition provides clues to environmental conditions. The presence of shallow, freshwater species of ostracodes in the oldest part of the core indicates that there was less than 2 m of water covering

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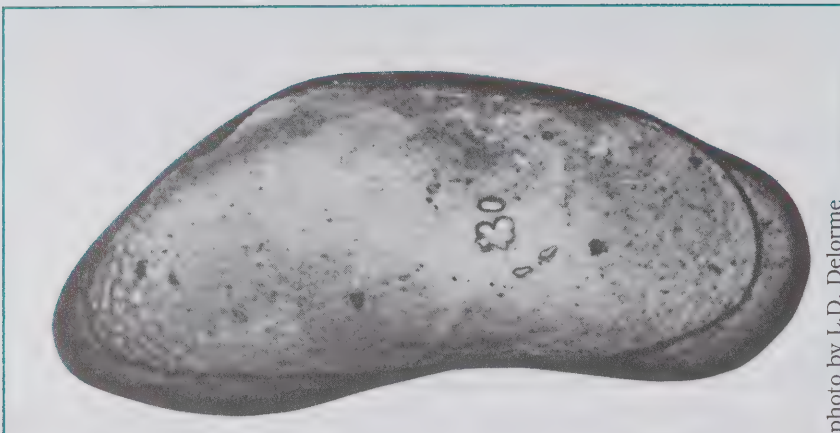


photo by L.D. Delorme

This is a microscopic view of *Candona ohioensis*, a species of ostracode typically found in Lake Ontario. Its presence in recent Hamilton Harbour sediments bears witness to the strong link between the two water bodies.

the area during the marsh period. The species assemblage was entirely different from that of historic Lake Ontario, suggesting that the marsh was isolated from the lake and fed by intermittent streams.

The physical properties of sediments also provide clues to environmental changes. Dr. Norm Rukavina found increasingly sandy sediments above the organic section of the

Ostracodes are conspicuously absent in the last 19 years of the core record...

core. This suggests that the rising water level in Lake Ontario eventually created an open link with the Harbour, transforming it from a fluvial marsh into a shallow bay. The sediments in the bay were strongly agitated by waves off the lake which washed away the fine grained material, leaving only the coarser sands behind.

Uniform, fine-grained sediments begin to appear in the younger, uppermost part of the core. These sediments indicate that

as the water level in the Harbour continued to rise, the water body was more protected. This allowed for an increase in both the variety and number of ostracodes, as well as the occurrence of typical Lake Ontario species. A sandbar located at the mouth of the Harbour now sheltered it from waves off the lake. This same bar still protects the Harbour to this day.

The soft, soupy, organic rich muds at the top of the core correspond to the deeper, less agitated harbour that we see today, and testify to the tremendous increase in particulate matter deposited by municipal and industrial discharges. Ostracodes are conspicuously absent in the last 19 years of the core record (i.e. since circa 1973) and the sediments are disturbed by shipping and dredging activities. Environmental conditions in the Harbour deteriorated

as industry flourished along its shores. Furthermore, although diatoms (i.e., algae with silica skeletons) are found throughout the core, those corresponding to the last 50 years bear abnormalities which may be caused by pollutant stress.

Searching for dates

Ascertaining dates for the middle region of the core is difficult due to the low quantity of organic matter. Scientists from the University of Waterloo have been very successful in finding relative dates on the core by analyzing fossilized pollen.

The explosion in ragweed pollen (referred to as the "Ambrosia horizon") peaks in the fossil pollen record at around 1830, when Europeans cleared the forests around the Great Lakes region to make way for agriculture. Pollen records also chronicle the decline and rebound of the hemlock forest about 4000 years ago.



photo courtesy of N. Rukavina

Dr. John Coakley analyzes the opened sediment core from Hamilton Harbour.

Pinpointing undesirable trends

Sediment core analysis represents one of the few tools available for scientists to assess prehistoric environmental conditions. The Hamilton Harbour study testifies to the power of sediment analysis by tracing dramatic changes in the landscape and documenting important environmental trends, especially during the last century. Apart from its historical

interest, the core provides background information about the Harbour in its natural, uncontaminated state. This gives scientists a baseline for evaluating the environmental impacts of industrialization and settlement, thereby aiding efforts to identify and address undesirable trends. ~~~~~

Contact:

Dr. John Coakley
Dr. Norm Rukavina
Dr. Denis Delorme

Biological markers used in sediment analysis

The presence of specific chemical compounds in lake sediments can be used to pinpoint the origins of materials found in these deposits. Dr. Richard Bourbonniere, Rivers Research Branch, and his colleagues used these biological markers to track the environmental changes which took place in the Rochester Basin of Lake Ontario over the last two centuries.

The scientists retrieved sediment cores from the Basin which contain materials dating back to the early 1800s. Analysis of these sediments revealed an increase, beginning in the mid-19th century, in the concentration of alkanes and fatty acids typical of tree waxes. This coincides with the clearing of natural forests to plant crops, which increased soil erosion and allowed greater amounts of plant material to be washed into the lakes.

The scientists recorded a similar surge in alkanes and fatty acids since the early 1950s, but in this case the specific chemicals were characteristic of microscopic algae. This parallels

the post-war population explosion and urban expansion which greatly elevated the amount of nutrients draining into the Great Lakes, and eventually led to excessive algal growth in some areas. Specific hydrocarbon compounds found in sediments from this time period signify a progressive increase in petroleum-based contaminants and other urban pollutants.

Dr. Bourbonniere is employing similar techniques to study contaminant trends within the Lake Athabasca watershed of northern Alberta. There the concern is how to distinguish between airborne and upstream contaminant sources and to compare natural changes in the basin to those caused by human influence.

Contact:

Dr. Richard Bourbonniere

Reference:

Bourbonniere, R.A. and P.A. Meyers, 1992. Anthropogenic influences on hydrocarbon contents of sediments deposited in Lake Ontario since 1800. 35th Ann. Conf., IAGLR-92, May 31-June 4, 1992, Waterloo, Ontario, Abstract p56.

Characterizing sediment settling

Understanding the settling characteristics of fine-grained sediments is important to the design and operation of reservoirs and settling ponds. Unlike coarser materials, fine-grained sediments (e.g., clay) do not usually settle as individual particles, but instead clump together in a process called flocculation.

Dr. Bommanna Krishnappan, Rivers Research Branch, has developed a computer model which realistically predicts the settling times of fine-grained sediments because it accounts for this flocculation phenomenon. The model can be used to evaluate the use of settling ponds to trap contaminated fine sediments from agriculture and other sources.

Contact:

Dr. Bommanna Krishnappan

Reference:

B.G. Krishnappan, 1992. FLOCSETL: A computer model to predict settling and flocculation of fine-grained sediments in water columns: User manual. NWRI Contribution 92-101.

Keeping the kokanee in Kootenay Lake

Threatened by overfishing and fierce competition for food, the kokanee salmon population of Kootenay Lake, British Columbia, is rapidly dwindling. What's more, if the kokanee disappear, so do their predators, the Gerard trout, the largest rainbow trout in the world and found only in Kootenay Lake.

Part of the problem involves a shrimp (*Mysis relicta*) which outcompetes the salmon for zooplankton - the mainstay of the kokanee diet. Ironically, this shrimp was introduced into the lake as a food source for the kokanee, but the salmon are unable to prey upon them effectively. In an effort to feed the starving kokanee, the B.C. Ministry of the Environment is injecting a chemical fertilizer into the lake, in hopes that this will jump start the food chain. The fertilizer is intended to stimulate the growth of phytoplankton, which in turn will enhance the zooplankton populations that the kokanee feed on.

However, one of the greatest challenges is to apply the fertilizer in the right place at the right time. Water currents can concentrate randomly applied fertilizer into areas where it is not wanted. This can lead to excessive algal growth along the shores of the lake and wasted money. A team of NWRI scientists and technical staff are collaborating with the Civil Engineering Department of the University of British Columbia (UBC), and the Institute of Ocean Sciences, British Columbia, to optimize the application process.

The scientists are evaluating different methods for applying the fertilizer by injecting an environmentally benign red dye

into the lake to reveal dispersal patterns. Data collected during the summer are being analyzed, and by early next year the scientists hope to recommend procedures which will achieve optimal results. The data will also be used in a numerical model of the Kootenay Lake food web being developed by UBC's Fisheries Department.

Since the life cycle of a kokanee salmon is four years, it will take at least that long to ascertain

whether the fertilizer is enhancing the salmon population. However, early indications regarding its impact on primary production can be obtained as early as next year. In the meantime, the Ministry of the Environment has imposed catch limits to help offset the waning salmon population.

Contact:

Dr. Paul Hamblin
Mr. Farrell Boyce



photo by B. Moore

After the storm Managing urban stormwater

Jiri Marsalek, Rivers Research Branch, recently co-authored a paper which reviews our changing perceptions of urban stormwater and its management.

Historically, urban stormwater has been managed on the premise that it is a nuisance and should be drained from developed areas as quickly as possible. Little consideration was given to the environmental impacts of stormwater.

In the last 25 years, however, our knowledge of these impacts has grown. We now understand that urban stormwater can have a profound influence on water resources in the watershed. It can widen streams, increase erosion, and cause local and downstream flooding. Moreover, the pollutants found in stormwater can have far-reaching effects on aquatic ecosystems, including impaired recreational water uses, toxic contamination, loss of aquatic

habitat, and destruction of coldwater fisheries.

The growth of the sustainable development philosophy has inspired a change in our attitudes towards stormwater management. Much progress has been made in controlling the amount of pollutants in runoff and integrating stormwater management methods and structures into the urban landscape. Of particular note is evolution of stormwater

ponds which control the quantity and quality of the runoff while decreasing erosion, recharging groundwater, and providing valuable recreational amenities.

The paper emphasizes the potential for reusing stormwater to meet some of our future water needs. It also summarizes the experience gained from several management case studies and outlines suggestions for future research into this issue. Some of these research issues are

currently pursued in a collaborative study with Queen's University in Kingston, Ontario.

Contact:

Jiri Marsalek

Reference:

MacRae, C.R. and J. Marsalek, 1992. The role of stormwater in sustainable urban development. Proceedings of the Canadian Hydrology Symposium, No. 19-1992, Hydrology: Its Contribution to Sustainable Development, Winnipeg, Manitoba, June 15-17, 1992, pp372-389.

Measuring ice jam thickness

River ice jams are a major cause of flooding and related damage in Canada. They threaten navigation, damage structures (such as bridges), interfere with hydroelectric power production and destroy aquatic habitat. At the same time, our serious knowledge gaps regarding this phenomenon have limited our abilities to forecast ice jamming and avoid these consequences.

The difficulty in measuring the thickness of these jams is one major research impediment. Ice jams formed during the spring thaw are usually unstable and can't be safely measured by drilling through the ice. Other means for measuring ice jam thickness either rely on indirect measurements or require further development. Dr. Spyros Beltaos, Rivers Research Branch, working with Jerry Ford and Niels Madsen, Research Support Division, and Bill Moody, Research and Applications Branch, have developed a remote technique to safely measure the thickness of these jams.

The team has designed a drogue which loses its buoyancy once it encounters an ice jam. It sinks

to avoid the obstruction and then bobs back up to the bottom of the ice. As the river current drags it along the bottom of the ice jam, a radio transmitter reports the water pressure to the field party. Simple calculations are then used to convert this measurement into the thickness of the ice. The drogue is easy to operate, safe to use and has performed well in field trials on the Restigouche River, New Brunswick, and the Thames River, Ontario. The team may alter the drogue in the future so it can be released from and monitored by helicopter.

Knowing the thickness of ice jams will help us to predict how jams form and release, and estimate the severity of their effects. It will also help identify vulnerable points where blasting or ice breaking would be most effective in removing the jam.

Contact:

Dr. Spyros Beltaos

Reference:

Ford, J.S., Beltaos, S., Moody, W.J. and N. Madsen, 1991. Remote measurement of ice jam thickness. NWRI Contribution 91-80.



photo by S. Beltaos

GOING WITH THE FLOW: Frank Dunnet, Research and Applications Branch, activates a radio transmitter inside the buoyant drogue.

The impact of waste tires on aquatic ecosystems

Close to 27-million rubber tires are discarded annually in Canada. Since rubber is considered to be relatively safe in the environment, many of these waste tires are re-used in road fill, fenders, artificial reefs and floating tire breakwaters. There have been few studies to determine the effects of placing tires in aquatic environments, and recently there has been speculation that tires release contaminants that may harm some aquatic organisms. Craig Bishop, Research and Applications Branch, along with Dr. Kristin Day and Janice Metcalfe-Smith, Rivers Research Branch, led a multidisciplinary study on the impact of tire leachate on the aquatic environment.

The team contracted B.A.R. Environmental Ltd. to perform toxicity tests using leachates from three types of car tires: new

tires, four-year-old used tires, and scrap tires that have been part of a floating tire breakwater for over ten years. The contractors performed acute lethality tests of the leachate on rainbow trout (*Salmo gairdneri*), fathead minnows (*Pimephales*

Close to 27-million rubber tires are discarded annually in Canada.

promelas) and a species of zooplankton (*Daphnia magna*).

The leachates produced by the ten-year-old tires showed no toxicity to any of the test organisms. Leachate from new tires and the four-year-old tires were toxic to rainbow trout, although the other two test organisms remained unaffected. Further studies characterized

the toxic substances as persistent and non-volatile.

The impact of these results still needs to be fully evaluated. The specific contaminants have not yet been identified, but NWRI scientists continue to analyze samples of the tire leachate to determine their chemical composition.

Many agencies have shown interest in the study, including the Marine Forests Society (a society proposing to use scrap tires to construct marine habitat) and other government agencies. The study was partly funded by the Department of Fisheries and Oceans.

Contact:

Craig Bishop

Reference:

BAR Environmental Ltd., 1992. Evaluation of the Potential Toxicity of Automobile Tires in the Aquatic Environment.

Predicting the migration of radionuclides

Nuclear accidents (such as that at Chernobyl) deposit radioactive elements across surrounding landscape, where these elements slowly leach into receiving waters. Considerable quantities of radionuclides were also released into the environment during atmospheric testing of nuclear weapons throughout the 1950s and early 1960s. Dr. Sewak Joshi, Lakes Research Branch, has developed a model which predicts the aquatic migration of radionuclides that are uniformly distributed over drainage basin soils.

Once these radioactive pollutants land on the soil, they can either migrate deeper into the ground or be removed in surface runoff. The chosen

pathway depends upon whether the radionuclide is present in solution or attached to soil particles. Dr. Joshi has incorporated this concept into his predictive model. The method requires only a few field measurements, rendering it much simpler and faster than previous prediction methods.

The model was evaluated for the "bone-seeker" radionuclide strontium-90. Measurable levels of this radionuclide are present throughout the northern hemisphere as a result of fallout from prior weapons testing. The model-predicted fluxes of strontium-90 in the Ottawa and Winnipeg rivers compared favourably with long-term measurements.

This approach will help improve the ability to predict the consequences of nuclear accidents. It can also be extended to calculate the removal of other organic and inorganic pollutants which are uniformly distributed over drainage basins. Dr. Joshi intends to use this model to improve predictions of the persistence of radionuclides in the Great Lakes.

Contact:

Dr. Sewak Joshi

References:

Joshi, S.R. 1992. Prediction of runoff transport of fallout ⁹⁰Sr. Submitted for publication in Health Physics.

Informing the public

Two displays produced for our 1992 Open House are being adapted for teaching purposes outside the Institute.

The Ontario Science Centre has expressed interest in using a computer program developed by Dr. Efraim Halfon, Lakes Research Branch, in the Great Lakes section of their 1993 special exhibition on the environment. The program uses computer animation, voice and sounds to demonstrate how Environment Canada scientists study dissolved oxygen in Lake Ontario. A copy of the program is being modified by the Science Centre for their specific needs.

Furthermore, several local teachers and environmental non-government organizations have also expressed interest in a computer screenshow on acid rain, produced by Dr. Dean Jeffries, Rivers Research Branch. The screenshow graphically presents general information on the origin of acid rain, its geographic occurrence in Canada and its effects on aquatic ecosystems. Copies of the program are available upon request.

Contact:

Dr. Efraim Halfon
Dr. Dean Jeffries

1992 Vollenweider Lecture

Dr. Ulrich Förstner was awarded this year's R.A. Vollenweider Lectureship in Aquatic Sciences. He presented his lecture "Contaminated Aquatic Sediments and Waste Sites as Toxic Chemical Time Bombs" on October 7 at the Canada Centre for Inland Waters.

The lecture described a mechanism by which some "benign" waste deposits or contaminated sediments can eventually produce disastrous environmental damage. The buffering capacity of the soil or sediment in these sites can be exceeded as geochemical conditions change, resulting in an abrupt release of toxic chemicals into the environment. Dr. Förstner described the Elbe River estuary/Hamburg Harbour area as one example of these "time bombs". He went on to advocate proactive assessment and management for these sites.

During his visit, Dr. Förstner had a chance to talk with scientists from NWRI and the University of Waterloo. He also observed the environmental damage at Love Canal first-hand.

Dr. Förstner was awarded the Vollenweider Lectureship for his outstanding contributions to the field of environmental geochemistry. He is Professor (Director) of the Division of Environmental Protection Technology at the Technological University of Hamburg-Harburg, sits on the Board of Directors for the Water Chemistry Group of the German Chemical Society and is a member of several prestigious national and international organizations. He has authored over 240 publications, including the textbooks *Metal Pollution in the Aquatic Environment*, and *Metals in the Hydrocycle*.

The Vollenweider Lectureship is awarded annually in honour of Dr. Richard A. Vollenweider, who retired as NWRI's senior scientist in 1982. Dr. Vollenweider's research into eutrophication revolutionized modern limnology, and his name can be found on the United Nations Environment Programme's "Global 500 Roll of Honour".



NWRI *Digest* is the public newsletter of the National Water Research Institute, Canada's largest freshwater research establishment. The Institute conducts a comprehensive program of research and development in the aquatic sciences which it undertakes in partnership with water management agencies and water science communities in Canada and around the world. Our research creates knowledge and develops expertise on water quality issues important for sustainable water resource use and the preservation of freshwater ecosystems.

Suggestions, comments and further enquiries concerning NWRI *Digest* are welcomed. Articles may be reprinted upon permission from the editor. Please write to:

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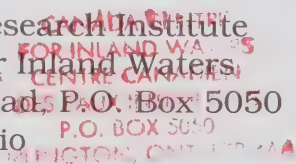
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THE NEWSLETTER OF THE NATIONAL WATER RESEARCH INSTITUTE

Northern challenges

NWRI scientists study contaminants in the Canadian Arctic

Peter Amarualik has lived almost his entire life north of the treeline. As with all Inuit, Peter shares a historic and intimate link with the land. For thousands of years the Inuit have relied on natural foods for their existence in the harsh and challenging arctic climate.

But this once pristine arctic environment is threatened by organic pollutants such as polychlorobiphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs) and pesticides. Most of these chemicals are produced and used thousands of miles south in North America and Eurasia, but are transported to the Arctic by air and water. Once in the Arctic, the low temperatures and the minimal sunlight during the winter season greatly inhibit the natural breakdown of these compounds. Melting snow then releases these pollutants into the aquatic ecosystem.

The high proportion of body fat in arctic animals acts a sink for many persistent chemicals. This leads to the accumulation of contaminants in animals at the top of the arctic food chain, such as fish, seals, whales and polar bears. The chemical burdens of these animals also raises concerns related to the diet of indigenous people who may depend upon them for their diet

(Kinloch et al. 1992). Since the cause of this regional problem is clearly international, the solutions will require international co-operative actions based on solid scientific knowledge.

Air, Water and Snow

Amarualik serves as a field technician for NWRI scientists working to address the problem of contaminants in the Arctic. The team of Lakes and Rivers Research

NWRI research responds to policy objectives established under the Arctic Environmental Strategy, and findings are reported directly to science managers for appropriate response. Our scientists work in close cooperation with many other government and non-government agencies to gather and evaluate information related to the origin, trends and fate of trace organic pollutants in the Arctic. Their studies take them to the northern extremes of Canada and often subject them to temperatures of -30°C and below.

The high proportion of body fat in arctic animals acts a sink for many persistent chemicals.

Branch scientists are principally funded under the Green Plan's Arctic Environmental Strategy. The Strategy, announced in May 1991, aims to preserve and enhance the integrity, health, biodiversity and productivity of the Arctic ecosystem. The action plan was developed by the Department of Indian and Northern Affairs in consultation with other federal departments, territorial governments and national native organizations. Its four-pronged approach addresses environmental problems related to contaminants, waste, water quality and quantity, and environment / economy integration.

Throughout the Canadian Arctic, snow samples are being collected to determine the annual deposition of contaminants from the atmosphere (see page 3). Rivers across the Northwest Territories are also being sampled to determine the sources of riverine contaminants and their contribution to the pollutants found in the Arctic Ocean (see page 7). In the west, NWRI scientists are comparing the relative importance of local and atmospheric sources of contaminants to the Yukon River basin (see page 6). Still others are studying the pathways and behaviour of contaminants in freshwater systems by focussing on a small lake basin located on Cornwallis Island, Northwest Territories (see page 3). Finally, at about 1100 km south of the North Pole, NWRI scientists are studying



historic trends in contaminants by analyzing the chemical composition of snow and ice preserved in the Agassiz Ice Cap on Ellesmere Island (see page 6).

These studies combine with other national and international research initiatives to fulfil specific knowledge requirements identified under the Arctic Monitoring and Assessment Program (AMAP). The AMAP is a major component of the Arctic Environmental Strategy, signed by the eight circumpolar countries which share jurisdiction of the Arctic. The AMAP is directed by an international Task Force which oversees the development and implementation of a series of plans to ensure collection of relevant and comparable circumpolar data under five themes: freshwater, atmosphere, marine, terrestrial and human health. The Canadian delegation is led by Dr. David Stone of Indian and Northern Affairs, and includes Dr. Rod Allan, Director of the Lakes Research Branch at NWRI.

Russian Partners

Canada and Russia hold the largest geographical interests in the Arctic and in 1991 a workplan was developed between the two countries to undertake cooperative research. This workplan is led by Indian and Northern Affairs but much of the work is undertaken by scientists within Environment Canada and Fisheries and Oceans Canada. Within Environment Canada, the main participants are the Atmospheric Environment Service, the Canadian Wildlife Service and NWRI.

NWRI scientists are pursuing cooperative interests with the world-renowned Arctic and Antarctic Research Institute (AARI) in St. Petersburg, Russia. Much of the AARI research into trace organic contaminants in the Arctic coincides with NWRI responsibilities in Arctic Canada. Steps are now being taken to assess the comparability of existing data between the two institutes and to develop a cooperative, bilateral program for

the future. This kind of cooperative work will prove invaluable in providing both a better understanding of contaminants in the arctic ecosystem and the scientific basis for sound management decisions.

Contact:

Dr. Rod Allan

Reference:

Kinloch, D., Kuhnlein, H., and D.C.G. Muir, 1992. Inuit foods and diet: a preliminary assessment of benefits and risks. *The Science of the Total Environment* 122: 247 - 278.

Contaminant Origins

The atmospheric transportation of semi-volatile trace organic compounds and other contaminants to the Arctic is thought to occur primarily during the winter season when the polar front extends southward into the industrial and agricultural heartlands of North America, Europe and Asia. The general winter atmospheric circulation pattern for the northern hemisphere, as illustrated here, is characterized by movement of air masses from the Eurasian continent into the Arctic with dispersal out over North America. During the summer, atmospheric circulation is dominated by flow off the north Pacific and Atlantic with outflow over both Eurasia and North America.



There are few local sources of waste in the Arctic. One group of prominent local sources is the abandoned Distant Early Warning (DEW) sites. This chain of radar stations established across the North in the 1950s formed part of the continental defence system until advanced technology rendered them obsolete a little over a decade later. The PCBs which contaminated many of these sites have been addressed in an interdepartmental cleanup which began in 1985. Other waste sites that may be hazardous, or merely unsightly, include numerous drum disposal sites as well as both active and abandoned mine sites. Impact from such sites tends to be localized and is generally not the focus of the NWRI research program. One possible exception is the Yukon River / Lake Laberge system where high levels of pesticides and PCBs found in the aquatic system may have resulted in part from waste disposal during and after construction of the Alaska Highway (see page 6).

Snowfall brings airborne pollutants down to earth

Precipitation is one means by which the atmosphere is scrubbed of its burden of contaminants. Snow, the dominant form of precipitation throughout the arctic, is very effective at scavenging certain compounds. Consequently, the measurement of contaminants in annual snowpack provides a good first estimate of contaminant deposition from the atmosphere during the winter season.

For several years, NWRI scientists have documented the annual contaminant deposition to the arctic snowpack. In 1992, the number of sampling sites was expanded to cover the entire Canadian Arctic (see centerspread). Sampling begins in the Yukon and Mackenzie Valley in mid-March and continues through to the high arctic in May. This ongoing work supplies data for a snow melt model which will provide a total contaminant transport budget for the Arctic region. The contaminant runoff from the intensive basin studies on Amituk Lake (see below) and the loadings determined at the mouths of major river systems (see page 7)

will provide calibration and evaluation terms for this model.

Snow Collectors

NWRI scientists have designed large surface area snow collectors in an effort to better understand precisely when contaminants are deposited to the snowpack over the winter season. These collectors measure persistent organic pollutants in fresh snow on a weekly basis. During the winter of 1992-93, five of these collectors will be operated (see centerspread for locations). In addition, a small area snow collector will be operated in a high snowfall area of northwestern British Columbia (approximately 40 km from the Pacific Ocean) to compare the chemistry of snow from Pacific air masses to that from arctic air masses.

Two of the snow collectors are co-located with air samplers which measure the same contaminants in the atmosphere and are operated by the Atmospheric Environment Service. Together, these data will provide a better understanding of the sources and timing of delivery of these contaminants to the Arctic.

Arctic vs Great Lakes

Data from the snow collector at the Mould Bay weather station (see centerspread) clearly demonstrate that remoteness from the source of pollutants provides the Arctic with little protection. Measurements retrieved from the collector during the winter of 1990-91 revealed daily deposition rates of PCBs that are comparable to those measured for the Great Lakes region. Even more surprising, the daily deposition rate of the chlorinated pesticide lindane at Mould Bay averaged 3.2 ng.m^{-2} , which is about 100 times higher than the average reported rate for the Great Lakes region.

Contact:

Dr. Dennis Gregor

References:

- 1) Barrie, L. A., D. Gregor, B. Hargrave, R. Lake, D. Muir, R. Shearer, B. Tracey, and T. Bidleman, 1992. Arctic contaminants: sources, occurrence and pathways. *Science of the Total Environment* 122:1-74.
- 2) Gregor, D. J. and Wm. Gummer, 1989. Evidence of atmospheric transport and deposition of organochlorine pesticides and PCBs in Canadian Arctic snow. *Environmental Science and Technology* 23(5):561-565.

Melting snow carries pollutants to the ocean

Atmospheric contaminants that accumulate in the snow are released during a very short time in the spring when the snow melts and is washed out through rivers and lakes into the Arctic Ocean. However, since contaminants can be bound to substrates, taken up by organisms, or otherwise transformed *en route*, the full amount of chemicals deposited in the snow doesn't necessarily enter the marine environment with the melt water. NWRI scientists are working to quantify the pathways and behaviour of these contaminants as they are transported towards the ocean.

The team, working in cooperation with the Inland Waters Directorate

(Yellowknife) and with students from the Arctic College in Iqaluit, are developing a hydrological and chemical budget for a small lake basin on the east coast of Cornwallis Island, Northwest Territories (see centerspread). In 1992, a semi-permanent field camp and year-round, automatic weather station were established at Amituk Lake. Initial field measurements permitted an estimate of the chemical transport of surface runoff into and outflow from the lake.

During 1993, the field season will be extended to allow chemical and flow measurements for the entire runoff period, which lasts roughly from June until late August when temperatures plummet and the rivers freeze once again. Further

studies will include an investigation of lake processes which affect the distribution and movement of organic contaminants and a study of the exchange of specific contaminants between the snowpack or lake surface and the atmosphere.

Hydrochemical data from this study will be used in a model being developed at the University of Toronto. This mass balance model will be generally applicable to arctic lakes for a variety of contaminants.

Contact:

Ray Semkin

ARCTIC CONTAMINANTS

TRAVAUX DE RECHERCHE SUR L



← Dr. Andrew Peters collects a water sample from the Thelon River.

Andrew Peters recueille un échantillon d'eau de la rivière Thelon.



- 1992 snowpack sampling sites



- 1992 river sampling sites



- weather stations



- Yukon River basin

A

- Amittuk Lake study basin

B

- Agassiz Ice Cap

- Southern boundary of continuous permafrost



① - Alert weather station



② - Mould Bay weather station



③ - Whitehorse



④ - Tagish



⑤ - Snare Rapids



⑥ - Fraser, B.C.



- Area north of tree line



- sites de prélèvement de la neige accumulée en 1992



- sites d'échantillonnage des cours d'eau



- stations de météo



- bassin du fleuve Yukon

A

- études sur le bassin du lac Amittuk

B

- pergélisol Agassiz

- limite sud du pergélisol



① - station de météo d'Alert



② - station de météo Mould Bay



③ - Whitehorse



④ - Tagish



⑤ - rapides Snare



⑥ - Fraser, C.-B.



- région au nord de la limite des arbres

RESEARCH ACTIVITIES CONTAMINANTS DE L'ARCTIQUE

Snow samples are collected annually →
for contaminant analysis.

reka

Des échantillons de neige sont
recueillis chaque année pour
l'analyse des contaminants.

ite

aker Lake

Iqaluit



Eve-Lucie Bourque



↑ Peter Amarnalik collects a snow core
from the Amituk Lake basin.

Peter Amarnalik recueille une carotte
de neige du bassin lac Amituk.

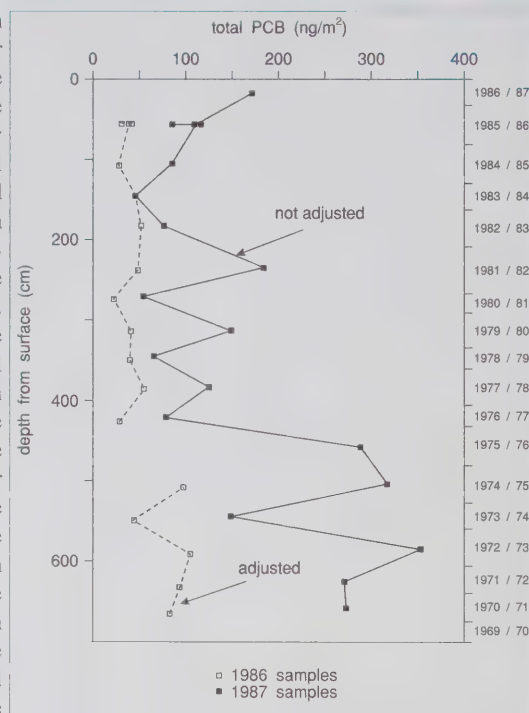
Contaminant history recorded in ice caps

Ice caps are vast masses of ice and snow that cover large land areas in the polar regions. Ice caps in the Arctic and Antarctic are built up of snow which has fallen over thousands of years. The snow and air bubbles locked in the ice cap provide a historic record of the chemistry of the earth's atmosphere at the time the snow was deposited. NWRI scientists are analyzing samples of snow and ice from an arctic ice cap to reveal the record of industrial and agricultural chemical pollution in the Arctic.

The first NWRI experiments began in 1986 on the Agassiz Ice Cap on north central Ellesmere Island (see site B on map) and determined that pesticides and other persistent organic pollutants could be quantified in the snow layers. This led to an extensive "dig" in the spring of 1987 to sample 17 years of snow accumulated on the ice cap.

The raw data indicate that PCB residue in the Ice Cap (solid line in the figure) decreased by a factor of about three between 1969-70 and

1986-87. Both the emission of these contaminants, their delivery or deposition to the Ice Cap, and possible revolatilization can vary annually due to natural phenomena. The dashed line in the figure is an attempt to adjust the PCB residues found in the Ice Cap for the variable delivery. Here the PCB data are normalized with a natural radionuclide derived from the earth's surface. As the releases of this radionuclide remain constant from year to year, variability in the abundance of the radionuclide in the snow can be assumed to approximate the variability in contaminant delivery via the atmosphere. These adjusted data suggest that the accumulation of PCBs in the Ice Cap decreased by approximately a factor of two over this 17-year period. While this is less than suggested by the raw data, it is nevertheless encouraging.



The Ice Cap is sampled annually to continue measurements of the deposition of persistent organic pollutants. A major expedition is planned for March 1993 to extend this contaminant profile back to the 1940's (about the earliest that any of the chlorinated compounds such as PCBs were used).

**Glacier ice
over 100 000 years
old is found at the
base of many
Canadian Arctic
ice caps.**

[Source: *A Primer on Water*]

Contact:

Dr. Dennis Gregor

References:

- 1) Barrie, L. A., D. Gregor, B. Hargrave, R. Lake, D. Muir, R. Shearer, B. Tracey, and T. Bidleman. (1992). Arctic contaminants: sources, occurrence and pathways. *Science of the Total Environment* 122:1-74.
- 2) Gregor, D. J., 1991. "Trace organic chemicals in the arctic environment". In: *Pollution of the Arctic Atmosphere*, W.T. Sturges (ed.), Environmental Management Series, J. Cairns and R. M. Harrison (Series Editors), Elsevier Science Publishers Ltd., Essex, England, pp. 217-254.

Contaminants in the Yukon River basin

On May 8, 1991, a Health Advisory was issued by the Yukon Medical Officer of Health on behalf of Health and Welfare Canada, advising "... people not to consume any burbot liver and to limit their consumption of lake trout fillets from Lake Laberge due to elevated toxaphene levels." All other fish were considered safe for consumption.

Unlike most of the contaminants in the Canadian Arctic, those found in

this region were once used locally. In fact, there may be contaminated disposal sites which remain unidentified. NWRI scientists, in cooperation with research partners from the Atmospheric Environment Service, Environmental Protection, Fisheries and Oceans, and Indian and Northern Affairs, are working to identify local contaminant sources and compare their contribution to local pollution to that of

atmospherically transported contaminants.

NWRI scientists performed an initial survey of the Yukon River basin in March 1992 to identify inputs to the river from known disposal sites. At that time, they found that the largest dump site in the area, located on the banks of the Yukon River downstream of Whitehorse, was not contributing significant amounts of PCBs to the river. In fact, the PCBs

in small ponds at the base of the dump had a chemical signature comparable to that of the snow in the headwater portion of the basin, which suggests a predominantly atmospheric source.

Currently, a more extensive sampling program is underway in

the basin to investigate year-round atmospheric deposition. Snow collectors are being operated at three sites in the basin (see centerspread), one of which is co-located with an air sampler. Furthermore, a rain and dust sampler will be installed and operated during the summer season. More intensive site

investigations and riverine contaminant loading measurements to Lake Laberge are planned for the 1993 field season.

Contact:

Dr. Dennis Gregor
Dr. Mehran Alaei

Contaminants in arctic rivers

Rivers comprise the largest source of freshwater to the Arctic Ocean. The Mackenzie River, the fourth largest of the world's rivers draining to the Arctic ocean, contributes approximately 16 per cent of the total riverine flow to the Ocean and drains about 1.8 million square kilometres. The combined volume of the Mackenzie and other northern Canadian rivers gives them the potential to transport large quantities of pollutants to the ocean, especially during the snowmelt season.

NWRI scientists are currently investigating arctic rivers to determine the quantity of organic contaminants in these rivers as well as the sources of these contaminants. These data will also


provide an estimate of total contaminant loadings to the Arctic Ocean from Canadian rivers for comparison with all other riverine sources.

Emphasis has been placed on the Mackenzie River. Scientists collected water and suspended sediment samples from three locations near the mouth of the river during the open water season. Eleven other major rivers in the Northwest Territories were also sampled to allow a comparison of contaminant levels. These data, although limited, will provide the first information regarding the transport of persistent organic pollutants in these rivers. All samples are being analyzed for over 150 organic contaminants such as pesticides, PCBs and PAHs.

Additional sampling is planned for 1993 to provide data for the rivers at different times of the year (e.g., when they are affected by seasonal changes such as ice cover and snowmelt). These data will for the first time characterize contaminants in northern Canadian rivers. In addition to providing information essential to Canada for managing our natural resources, these data will contribute directly to that part of the Arctic Monitoring and Assessment Program directed towards estimating riverine loadings of contaminants to the Arctic Ocean.

Contact:

Dr. Dean Jeffries
Dr. Andrew Peters

p Perhaps one of the most interesting personal advantages of working in the North is the spirit of cooperation and support that exists among personnel facing the natural elements and remoteness of the Arctic. NWRI scientists work closely with a variety of federal agencies and other organizations to share resources and develop joint research undertakings. Special mention must be made of the Department of Indian and Northern Affairs, as well as staff of the High Arctic weather stations and the Polar Continental Shelf Project for all their financial and research support. 

Our Major Arctic Research Partners

Environment Canada

Atmospheric Environment Service
(Downsview, Winnipeg and the High Arctic Weather Stations)
Environmental Protection (Whitehorse)
Water Resources Branch, Inland Waters Directorate
(Yellowknife)

Other federal departments

Department of Fisheries and Oceans
(Freshwater Institute Winnipeg, Manitoba; Institute of Ocean Sciences, Sidney, B.C.; Bedford Institute of Oceanography, Halifax, N.S.)
Energy, Mines and Resources Canada, Polar Continental Shelf Project
Indian and Northern Affairs Canada (Ottawa, Yellowknife and Whitehorse)

Other organizations and government agencies

Arctic College, Iqaluit
Government of Northwest Territories, Renewable Resources Department
Narwhal Arctic Services, Resolute Bay, NWT
Science Institutes of the Northwest and Yukon Territories
University of Toronto
Yukon College, Whitehorse



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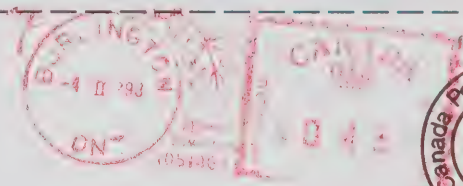
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THE NEWSLETTER OF THE NATIONAL WATER RESEARCH INSTITUTE

Up to Snuff Quality Assurance

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**Canadian
children speak
out on
Environment
Week**

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**Hamilton
Harbour
sediments
improving**

i
g
h ~ 6 ~

**Identifying the
sources of
crude oil spills**

t
s

Would you even attempt to draw a straight line with a crooked ruler? Probably not. In environmental science, a "crooked ruler" can lead to inappropriate management decisions, wasted dollars and hazards for both ecosystem and human health.

Never before have so many pivotal decisions regarding our environment, health and the economy depended on the quality of chemical data. In a field where one part per *billion* and one part per *million* are as different as Lake Superior and Love Canal, it is essential to put in place a series of checks and balances to ensure the credibility of chemical data.

NWRI has become a leading force in ensuring the quality of environmental data generated in many government, university and private laboratories through its Quality Assurance (QA) Project. The QA team coordinates and executes interlaboratory comparison studies to help identify sources of error. They also create Certified Reference Materials (CRMs) which are used to evaluate new equipment or methods, gauge laboratory performance and perform precision-oriented environmental research.

Round Robin Studies

Stacked in a poorly lit corner of NWRI are literally thousands of empty whisky bottles. No, your tax dollars aren't being spent on an expensive habit--the bottles are actually the container-of-choice for distributing water samples containing toxic organic substances. Samples of inorganic and organic toxic substances in both sediment and water are sent across the country in the QA team's interlaboratory (or "round robin") comparison studies.

Round robins allow program managers to see how their laboratories compare in terms of quality. They involve providing identical sets of environmental test samples to various laboratories. Each laboratory analyzes the sample for specific constituents and sends back the results to NWRI. The QA team compares the accuracy and precision of the test laboratories and prepares a summary and a final QA report. This valuable feedback can identify erratic performance, complete failure of a particular method, or operational blunders which may be generating bias or imprecise results. It also allows laboratories to see how they rate, thereby providing the impetus to initiate



Environment
Canada

Environnement
Canada

DIGEST 1

corrective actions and improve their competitive advantage. The QA team executes performance studies for a variety of environmental programs, including the Great Lakes Action Plan, the Fraser River Action Plan and the Long-Range Transport of Air Pollutants Program (LRTAP). Ultimately, the final measure of success for interlaboratory audits is improved performance. Figure 1 (*opposite page*) graphically depicts the dramatic improvement in one laboratory's performance due to participation in the NWRI QA program.

The LRTAP studies also highlighted the uncertainties in pH measurements used for the acid rain reports that air on the Weather Channel. Most of the five stations in eastern Canada are staffed by non-professionals trained by the Atmospheric Environment Service to take measurements of acid rain. Upon request, the QA team sent a set of control samples to each station and confirmed that there were some errors resulting from various factors, including a radio transmitter which was located near one of the stations. The errors have since been corrected, and NWRI regularly provides an acid rain kit to each station in order to ensure uniform and accurate readings.

Quality Spies

While interlaboratory studies can be extremely useful, they may not always represent the true quality of a lab's performance. Each of the participating laboratories is informed as to what is going on and has the opportunity to apply a little "spit and polish" to its lab performance.

One way to glean more realistic, unbiased information is to sneak a reference material into a batch of regular environmental samples. This backdoor (or "blind") approach often reveals intriguing insights into laboratory performance. This highlights many undiscovered problems and many program managers will swear by its usefulness in monitoring environmental laboratories.

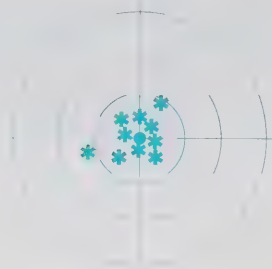
Certified Reference Materials

CRMs and their close cousin Reference Materials (RMs) provide an excellent means to hammer out the "kinks" in a crooked ruler. They are also used to evaluate the sensitivity and effectiveness of newly developed measurement techniques and equipment. The QA team sends these standard mixtures out across Canada and to a growing international market.

Both CRMs and RMs are stable, homogenous and well characterized reference materials. The difference between the two is a matter of stringency. The material for each CRM is tested at least 500 times by numerous methods to ensure that the chemical composition is certified within a very small degree of error. RMs are similar, but

Accuracy vs precision

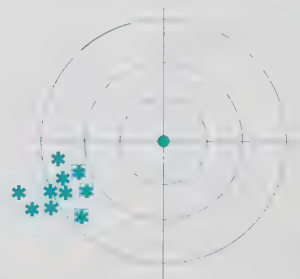
Accuracy and precision are considered by many to be synonymous, when in actuality they're quite different. Take a look at the diagrams below. The bull's-eye on each target represents the correct value of a standard sample that would be sent out to various laboratories.



When lab results are both precise *and* accurate (case 1), all the results are very close to the bull's-eye.



The scattergun effect in case 2 is an example of imprecise measurements. There's no real pattern to these results and the errors could represent shoddy laboratory techniques.



Case 3, on the other hand, could be described as *precisely inaccurate*. The same degree of error is incurred every time which often symbolizes a simple calibration or contamination problem which can be easily rectified once identified.

are analyzed less stringently and considered the forerunners to CRMs. CRMs and RMs are derived from natural sources. Keijo Aspila often frequents greenhouses to collect the large volumes of water required for RMs of toxic rain and acid rain. The rain is collected from thunderstorms of southerly origin in the hope of capturing elusive toxic chemicals that are carried in the atmosphere and fall to earth in rain.

The team prepares a wide range of RMs for water analyses and certified reference materials CRMs for sediment analyses. These include the world's first lake sediment CRMs for polynuclear aromatic hydrocarbons, chlorobenzenes, polychlorinated biphenyls and selenium. Each year adds new CRMs and RMs to the NWRI list, as the QA team expands its services.

Accrediting Laboratories

One way to ensure a uniform scale of quality across the country is through a national accreditation program. NWRI was instrumental in establishing the Canadian Association for Environmental Analytical Laboratories (CAEAL). CAEAL is an independent, not-for-profit association which provides an accreditation program for environmental laboratories. This program complements NWRI's interlaboratory studies. Initiated in 1989, the Association's members now number 275, with 100 certified labs.

CAEAL enhances competition between environmental

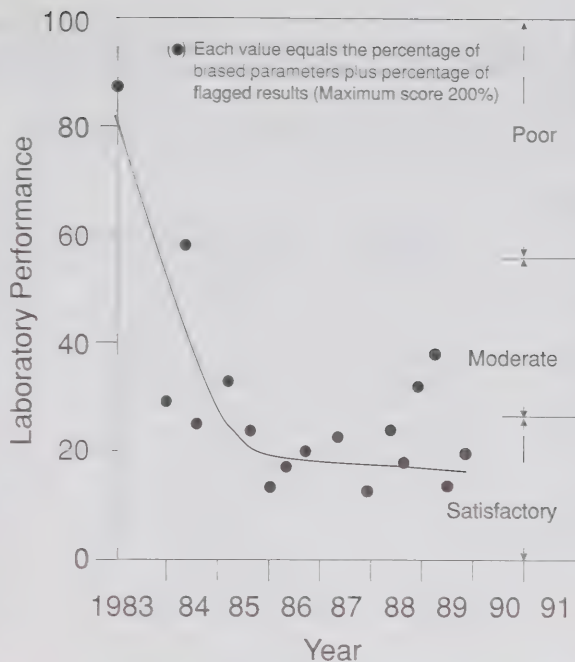


Figure 1: Lab Performance

laboratories -- pushing them to perform their best and meet exacting standards for quality. Already, several regulatory agencies require CAEAL (or equivalent) accreditation from their contracted environmental laboratories. While CAEAL traditionally deals with laboratories which perform chemical investigations, they will soon begin to accredit laboratories which perform biological testing.

Contact:

Alfred Chau
Keijo Aspila
Dr. John Lawrence (CAEAL)

Reference:

A Manual for Effective Interlaboratory Quality Assurance, coordinated by K.I. Aspila, NWRI Contribution 89-99.

1992-1993 GLURF recipients

Congratulations to this year's Great Lakes University Research Fund (GLURF) recipients! GLURF fosters multi-disciplinary partnerships between federal and university scientists, and encourages new scientists to study Great Lakes issues.

The 16 projects funded for 1992-93 will fill knowledge gaps in such areas as remediating contaminated groundwater, mapping pollutant point sources and monitoring changes in public perception of water pollution issues. These scientists submitted proposals which will be funded:

MCGILL UNIVERSITY
Dr. Jean-Simon Blais
MCMASTER UNIVERSITY
Dr. Martin Daly
Dr. Jim Kramer
Dr. Bill Morris
Dr. Jack Rosenfeld
MEMORIAL UNIVERSITY
Dr. Teofilio Abrajano
UNIVERSITY OF GUELPH
Dr. Ramesh Rudra

UNIVERSITY OF TORONTO
Dr. Lino Grima
Dr. Ken Howard
Dr. Brent Sleep
Dr. Gary Sprules
UNIVERSITY OF WATERLOO
Dr. George Dixon
Dr. Marie Sanderson
Dr. Bill Taylor
Dr. Richard Thomas
UNIVERSITY OF WINDSOR
Dr. Khosrow Adeli

Canadian children speak out on Environment Week

Once Upon a Time

by Robin Campbell

FINALIST: SENIOR DIVISION

Once upon a time there was a beautiful, clean world. The air was clear, you could drink the pond water, the dumps were empty and the roads were clean. But a long time later the air got smoggy, and the lakes and ponds were polluted with cans, bags and chemicals. The dumps became larger and more numerous, and the roads were the peoples' garbage cans. Now the environment is even worse.

If I were Prime Minister for a day, there isn't much I could do because it would take a few years to even start cleaning up the environment. And even then it would still be pretty messed up. What you can do is use composters, buy biodegradable items instead of degradable ones, and practice the 3 R's (reduce, reuse, recycle). Also, you can organize groups in your community to have a "trash" day once each month and go around your city and pick up any garbage you find and recycle it, if possible. Or plant trees. Maybe some people can go down to the dump and pick up any recyclable items that they find. And even on your own time, you can pick up any garbage you see when you go for a walk.

You can't do much in a day, but if everybody pitches in, maybe in a decade or so the world would be somewhat like "once upon a time." To fix the environment wouldn't be just for us, but for our children and theirs and theirs and so on. Land is the only thing that matters; the only

DIGEST 4

*Sometimes our most valuable insights into ourselves are reflected in the words of our children. As part of this year's Environment Week festivities, we organized an essay writing contest to let Canadian children tell us what sustainable development means to **them**. All the participating schools had the opportunity to learn about sustainable development through the 1992 Canada Centre for Inland Waters Open House. The essays show us how well our young visitors have incorporated this concept into their daily lives. Canadian children are developing a keen sense of environmental integrity and realize that they can make a difference in our world. Presented here are the three recipients of our "Environmental Citizen of the Future Award."*

thing that lasts. Do you want your children, grandchildren and great-grandchildren to breathe foggy, smoggy air; not being able to go for a swim without getting sick and living next to a garbage dump? It is bad now, but if this keeps up at the same rate there will be nothing left. If you start now and keep trying to help, you can have clean air, water and streets. I think that most people do want this but you have to help. Now.

Robin Campbell is currently finishing Grade 8 at Humbercrest School in Toronto.

Let's Take a Stand

by Krystal Langenberg

FINALIST: JUNIOR DIVISION

Would you like your children to see the beautiful trees, the lovely flowers or the cute little animals? Well then, "Stop Polluting!" If we don't, then our children won't be able to see these wonderful things. My essay is about the environment. It talks about the ozone layer, pollution, animals and how we should help our earth.

By the time our children are 20 years old, they will have to wear special suits to stop them from burning -- that is; if we keep on polluting the earth and destroying our ozone layer. The ozone layer is almost like a layer of skin. It protects us from the sun's harmful rays. Unfortunately, that layer of skin around the earth is getting thinner and thinner. The causes are cars, trucks, factories and us.

We are a major cause of pollution. We think that one little piece of garbage won't hurt the earth if we throw it on the ground. But since there are 26 million people in Canada, that would mean **26 million pieces of garbage**. Everyday, many of our older factories cause air pollution that will end up polluting our lakes in the form of acid rain.

Today, many of our animals are on endangered lists because of pollution and people taking away their places to live. Because of oil spills, like the one in Alaska, many birds and seals that were in the ocean ended up dying there. The oil got into their

feathers and fur coats and they could not fly or protect themselves from the cold.

There are many ways that we can help our environment. If we all try to do at least one thing every month, the earth will be a better place to live. Some of the things we should do are: plant a tree, turn the lights off after we leave a room, separate the garbage so that it is recyclable, pick up any garbage that we see lying around, turn the water off while brushing our teeth, re-use plastic grocery bags when we go shopping, and remember--try not to pollute our earth, we need it for our children.

Krystal Langenberg is currently finishing Grade 6 at St. Vincent School in Oakville.

Sustainable Development

by Lauren McEachern

FINALIST: PRIMARY DIVISION

I am very concerned about the environment. It needs to be cleaned up and I have an idea.


If all the schools across the world went around their neighbourhoods and picked up the garbage, it would make a big difference. We can make bigger fines for dumping garbage. To help air pollution, we should find a non-polluting form of transpor-

tation like bikes or we could take buses and subways to work, schools and stores.

Think of our poor rainforests. Just think that people could save one acre of rainforest for just \$25.

Lauren McEachern is currently finishing Grade 4 at Rolling Meadows Public School in Burlington.

Hamilton Harbour sediments improving


 Over \$700 million has already been spent by industry and municipal governments to reduce the amount of nutrients and contaminants entering Hamilton Harbour. A study by Lakes Research Branch scientist Dr. Micheline Hanna shows that the harbour's benthic community is starting to bounce back in response to these and other restoration measures.

The number and diversity of benthic invertebrates (bottom dwelling organisms) is one way to gauge the ecological stress caused by polluted sediments. During the 1960s, the benthic community of the harbour was typically composed of a few pollution-tolerant species.

Dr. Hanna's study revealed that the community is now much more diverse. Since 1964, the overall number of benthic invertebrate species has jumped from 13 to 31. At the same time, the number of pollution-tolerant oligochaete worms has dropped from 9 to 5. Moreover, the harbour is now home to types of worms and insects which are more sensitive to pollution, such as *L. profundicola*, *Dicrotendipes* sp. and *Parachironomus* sp.

While these improvements are substantial, the aquatic community still has a long way to go before it can be considered fully restored. The benthic community still reflects an environment that is nutrient-rich, and over 65 per cent of the sites that were

examined were diagnosed as moderately to heavily polluted.

Dr. Hanna sampled the sediments four times during the summer and found that species diversity was highest in August when the harbour waters were warmest. She recommends that future monitoring of benthic invertebrates focus on this time period to ensure a consistent assessment of the community's response to restoration measures. 

Contact:

Dr. Micheline Hanna

Identifying the sources of crude oil spills

Pinpointing the geographic origins of an oil spill is important to ensure that the parties responsible for the spill are accountable for its clean-up. Identifying the source of crude and partially refined oils has in the past been an imprecise process. Dr. Suzanne Lesage, Dr. Hao Xu and Susan Brown, Rivers Research Branch, have developed a novel method that uses petroporphyrins to identify the sources of unrefined oil spilled onto soil and into groundwater.

Petroporphyrins belong to a larger class of compounds called porphyrins that are commonplace in nature. Porphyrins provide the active centres for haemoglobin and chlorophyll molecules. They are located at the heart of many detoxifying enzymes found in both mammals and bacteria, and may play an important role in bioremediating contaminated soils and groundwater.

The petroporphyrins found in crude oil are the product of the metabolism of chlorophyll by microorganisms and are usually complexed with metals they have scavenged from the environment; predominantly nickel and vanadium. The chemical identity of petroporphyrins varies between sources, depending upon the biological conditions inherent to each site. Using High Performance Liquid Chromatography, the NWRI scientists can differentiate between these various

compounds based on the different alkyl substituents attached to each porphyrin ring. Each crude oil sample produces a distinct petroporphyrin "fingerprint" which links the sample to its geographic origins. By comparing these fingerprints, the NWRI team were able to distin-

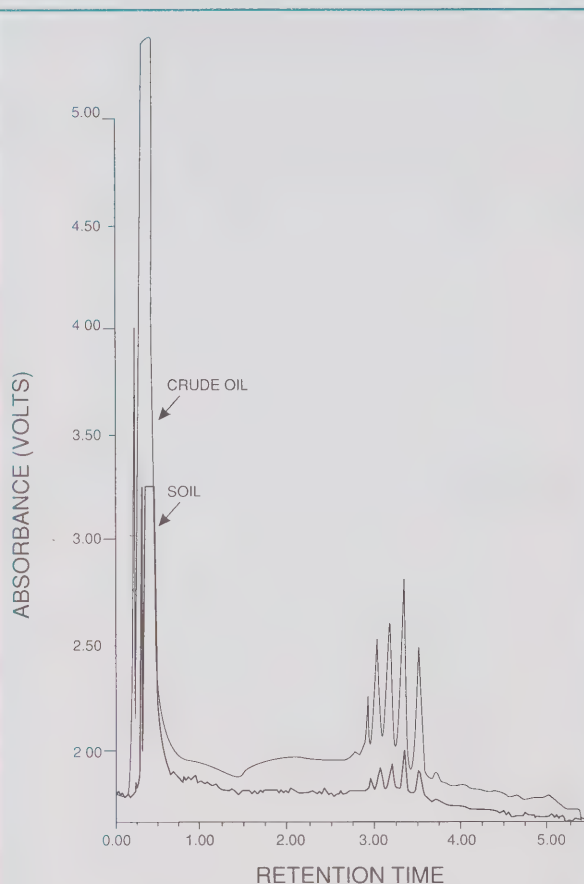
years after the spill occurred. The NWRI team is currently testing this theory by matching different samples of oil-contaminated soils from around southern Ontario to their origins.

Petroporphyrin analysis offers additional distinct advantages over other geomarkers that are either very biodegradable or arise from multiple sources (including the atmosphere) which can lead to inconclusive results. In contrast, petroporphyrins are unique to all unrefined and some partially refined petrochemicals. The new technique is also much simpler than previous petroporphyrin analyses which required the difficult and time consuming removal of the metals from each porphyrin ring.

Ultimately, a worldwide database of crude sources would allow a quick determination of a spill's origin by its chemical fingerprint.

References:

- 1) Xu, H., Lesage S., and S. Brown. Identification of Petroleum Contamination Sources by Fingerprinting of Petroporphyrins in Soil and Crude Oil Samples. Presented at the Canadian Association on Water Pollution Research and Control (CAWPRC), February 10, 1993.
- 2) Lesage, S., Xu, H. and L. Durham. The occurrence and role of porphyrins in the environment: Possible implications for bioremediation. *Hydrological Science Journal*, in press



These almost identical petroporphyrin fingerprints allow scientists to match a sample of oil-contaminated soil from Petrolia, Ontario back to its source.

guish between petroleum crudes from Alberta, the Northwest Territories, the East Coast, the North Sea and Venezuela.

Unlike many other compounds used in these studies, petroporphyrins break down very slowly in the environment. This means that oil spills can be matched to their sources even

PARTNERS IN RESEARCH:

Canada-Germany workshop at NWRI

Over the past decades, Canada and Germany have developed world-class expertise in specific areas of environmental and aquatic research and its applications. NWRI hosted a Strategic Planning Workshop from April 5-7 to enhance research partnerships between our two countries.

The workshop, organized under the auspices of a Memorandum of Understanding signed by both countries in 1990, included delegates from several German research institutes and Canadian participants from leading federal and university research centres, as well as three consulting companies. Intensive sessions in the areas of groundwater contamination and *in situ* bio-remediation, contaminated sediments, ecosystem health/ecotoxicology, and urban ecosystems defined the common interests and research priorities, designated lead agencies and established mechanisms for effective information exchange and technology transfer.

The workshop represents a new step in effectively pooling the expertise of both countries and continuing exchange of newly generated knowledge for the mutual benefit of the collaborating partners.

Contact:

Dr. Jan Barica

Dr. Robert Bisson

New book on groundwater

Learn various means of interpreting groundwater contamination data in *Groundwater Contamination and Analysis at Hazardous Waste Sites*. Co-edited by Rivers Research Branch scientist Dr. Suzanne Lesage, this 550-page reference describes investigations into the fate of toxic chemicals emanating from hazardous waste sites and contaminated groundwater. It discusses the hydrogeochemistry at U. S., Canadian, Australian, and German sites to reflect the different approaches used around the world.

Copies may be obtained from: Marcel Dekker, Inc., 270 Madison Avenue, New York, NY, 10016, tel: (212) 696-9000. Federal employees should write to Suzanne Lesage, Rivers Research Branch, NWRI.

NWRI receives UN designation

The United Nations Environment Programme (UNEP) has officially designated NWRI as the Global Environment Monitoring System (GEMS) Collaborating Centre for Freshwater Quality Monitoring and Assessment. UNEP's Executive Director, Elizabeth Dowdeswell, led the inauguration ceremonies at the Canada Centre for Inland Waters on April 8, 1993.

The designation is the first of its kind for a non-UN facility and recognizes the long-standing efforts of NWRI and the Canadian government in the GEMS/Water Programme. GEMS/Water is the only program to address freshwater issues on a worldwide basis. Its goal is to improve water quality monitoring and assessment capabilities in developing countries, thereby enhancing the abilities of these nations to manage their water resources. As part of Canada's involvement in GEMS/Water, NWRI maintains the Global Data Centre which stores water quality information sent in regularly by

countries participating in the programme. The Institute is also particularly active in the Programme's implementation in Asia and Latin America. RAISON, an environmental information system developed at NWRI, was selected for use in GEMS/Water and is being installed in several countries.

Canada is among the most vocal in insisting that monitoring be tied to the solution of real-world problems.

In opening the Centre, Dowdeswell said there was an "enormous role for those who can take data out of the world of collection and into the world of real problems which need real solutions." Canada is among the most vocal, she asserts, "in insisting that monitoring be tied to the solution of real-world problems." UNEP's designation complements the World Health Organization's designation of the Institute as the Collaborating Centre for Surface and Ground Water Quality.

Contact:

Dr. Robert Bisson



NWRI *Digest* is the public newsletter of the National Water Research Institute, Canada's largest freshwater research establishment. The Institute conducts a comprehensive program of research and development in the aquatic sciences which it undertakes in partnership with water management agencies and water science communities in Canada and around the world. Our research creates knowledge and develops expertise on water quality issues important for sustainable water resource use and the preservation of freshwater ecosystems.

Suggestions, comments and further enquiries concerning NWRI *Digest* are welcomed. Articles may be reprinted upon permission from the editor. Please write to:

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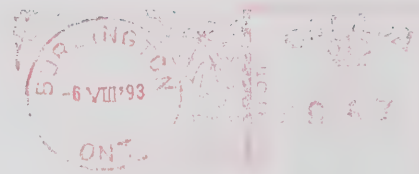
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THE NEWSLETTER OF THE NATIONAL WATER RESEARCH INSTITUTE

New problems for Lake Erie?

It seems that Lake Erie may never get a lucky break. First came the nutrient problems of the 1960s, when phosphorus loadings to the lake spurred excessive algal growth and threatened the stability of the Lake Erie fishery. The 1972 *Canada-U.S. Great Lakes Water Quality Agreement* (GLWQA) advocated actions which successfully reversed the trend towards increasing phosphorus loadings. Soon after, scientists recognized the threat from toxic chemicals. Once again, actions were begun to reduce or eliminate toxic chemicals under the GLWQA. Neither of these problems have gone away — they have only been improved or, in some cases, stabilized. Meanwhile, yet another force was proceeding unchecked to complicate the lake's problems.

New residents

The introduction of non-native species into the Great Lakes began in the 1800s with carp, alewife and sea lamprey. There are now 139 non-native species inhabiting the lakes, one-third of which have appeared in the last 30 years. At least 13 species cause significant ecological and economic damage. While the GLWQA was taking great strides in water quality, these invaders were quietly undermining the stability, integrity and biodiversity of the Lake Erie ecosystem.

Zebra mussels were first reported in Lake Erie during the late 1980s. As with phosphorus reductions, the mussels also reduce the amounts of algae. They filter algae from the water both as free swimming juvenile larvae, and later as adults fastened to shallow areas of the lake bottom.

Zebra mussels can filter enough algae to cause a marked increase in water clarity in some areas. While clarity is a cleanup goal in the Great Lakes, zebra mussels may consume enough algae to "starve" upper levels in the food chain, including certain species of fish. This is a serious concern because of the high value of the fishery in Lake Erie, estimated at over \$500 million annually. The success of the fishery depends upon the type, quantity and edibility of the fish. Zebra mussels may threaten all of these aspects by altering the flow of energy and contaminants within the food chain.

h **3**
i **Air**
g **conditioning**
h **scheme gets**
l **environmental**
i **OK**
g **4**
h **Scientists look**
t **for clues to**
s **missing eels**
g **5**
h **Water tests a**
t **success in**
s **First Nations**
community

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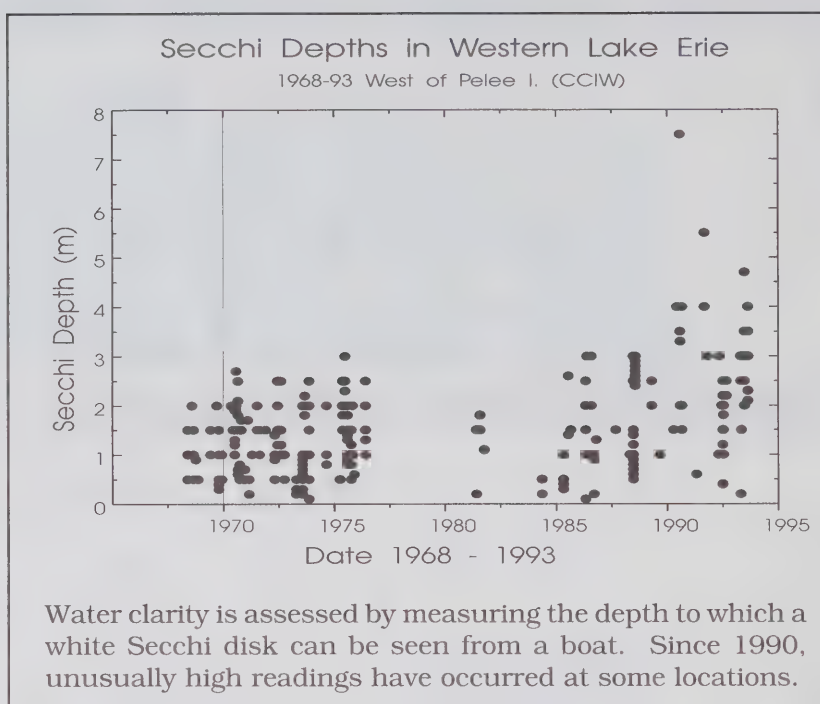
Water clarity records from 1990 provided some of the first signals that zebra mussels might be enhancing water transparency of some areas in the western basin. In other areas, however, water clarity remains similar to values reported in the 1960s. Research is clearly needed to understand the extent and variability of these effects and the relative contribution of other complicating factors, such as nutrient load reductions.

The role of these filter feeders on the fate of contaminants remains uncertain. The productivity of the lake may be one of its greatest natural defenses against the impacts of toxic chemical pollution. Scientists have proposed that the huge mass of biological material serves to "dilute" toxic contaminants within biota. What will be the consequences of a decrease in this material? Furthermore, will the increased concentration of toxic contaminants in zebra mussels inhibit the natural burial of these contaminants? Will changes in contaminant cycling result in contaminated fish?

Much of the background research on zebra mussels has focussed on biology and mitigative measures for industry. Recently, the federal government initiated new studies into the transfer of energy and contaminants within the lake's food chain. Ontario agencies have also been active in determining the impacts of changing conditions on the fish community and water quality. But, with the current level of knowledge, it is impossible at this stage to decide if there is a serious and urgent issue which demands government action. Recommendations to secure a sustainable resource must be based on an assessment and understanding of the actual ecosystem impacts of zebra mussels and other invaders, in the context of previous impacts on the lake.

Next steps

The need for improved knowledge and the requirement to coordinate and integrate Canadian research activities was recognized at a two-day workshop organized by the Department of Fisheries and Oceans and held at the Canada Centre for Inland Waters in mid-September. Representatives from Environment Canada, the Department of Fisheries and Oceans, Ontario Ministry of Natural Resources, Ontario Ministry of Environ-



ment and Energy, and Ontario universities agreed to a list of priority issues requiring further research.

NWRI scientists will focus their considerable background and expertise in Lake Erie research to address specific issues. Some of the new or expanded NWRI studies for 1993 and planned for 1994 will examine:

- ◆ the influence of zebra mussels on the fate of contaminants and nutrients within the lake ecosystem;
- ◆ the impact of zebra mussels filtering on the entire Lake Erie basin;
- ◆ the effect of mussel larvae on water quality and contaminant fate;
- ◆ the impact of mussels on the oxygen situation in the central and eastern basins; and
- ◆ the alterations in species composition due to invasion of non-native organisms.

As with other valuable resources, the continued conservation of Lake Erie requires strategic research to provide the context and knowledge for effective management decisions. The workshop represents the first step towards an integrated Canadian program to reveal the true situation in Lake Erie. Future efforts are planned to coordinate activities with U.S. agencies.

Contact:
Murray Charlton

Applying science

Air-conditioning scheme gets environmental OK

In the long list of environmental taboos, one that approaches the top is chlorofluorocarbon (CFC)-based air conditioning. Downtown Toronto office buildings use over 450 tonnes of CFC-11 and release an estimated 45 tonnes each year to the atmosphere during routine maintenance and mishaps.

The ongoing phase-out of CFC production in Canada lends urgency to the search for environmentally sensitive alternatives for coping with the summer heat. Fortunately for Toronto, the city may be perched on the edge of its own natural cooling source - Lake Ontario. The lake is a huge reservoir of very cold water. Below 80 metres in depth, the water temperature constantly hovers near 4°C.

Recognizing the potential environmental and economic benefits, Toronto city planners established a Deep Lake Water Cooling Investigation Group. Its mandate is to explore the feasibility of a facility that uses cold lake water to cool downtown Toronto and then pumps the warmed water back into the lake.

The group called in Lakes Research Branch scientists Farrell Boyce, Paul Hamblin and Bill Schertzer to study the physical effects of deep lake water cooling on Lake Ontario. Their team was completed by Dr. Danny Harvey, a climatologist from the University of Toronto, and mathematician Craig McCrimmon.

The scientists adapted a well established computer model to estimate the impact of the lake water cooling on the temperature regime of the lake. It confirmed what they already suspected -- that the Toronto facility would have a negligible impact on such a huge and naturally variable body of water. Even when global warming and moderate expansion are considered, the lake remains relatively unchanged by the deep lake water cooling scheme. While the cooling resource is not infinite, it seems adequate to service not only Toronto, but other urban centres on the lake.

Other studies instigated by the investigation group attest to the ecological "soundness" of the scheme. One study calculated a 90 per cent savings in the elec-

tricity required for cooling. That translates into reduced costs and a decreased reliance on fossil fuel-powered generating stations. The warmed water could also be treated and used to answer growing demands for municipal water supplies. Other schemes have been proposed to improve the quality of Toronto Harbour with clean water discharged from the cooling system.

The cooling facility awaits final approval and will undergo a formal environmental assessment and review process before installation.

References:

Boyce, F.M., Hamblin, P.F., Harvey, L.D., Schertzer, W.M. and R.C. McCrimmon, 1993. Response of thermal structure of Lake Ontario to deep cooling withdrawals and to global warming. *The Journal of Great Lakes Research*, 19(3):603-616.

Cooling Buildings in Downtown Toronto, Canadian Urban Institute, 1993. Final report on the work of the Deep Lake Water Cooling Investigation Group. Urban Focus Series No. 93-2. ISSN: 1183-2304. ISBN: 1-895446-03-1.

Toronto may be perched on the edge of its own natural cooling source

Maintaining biodiversity:

Scientists look for clues to missing eels

In 1985, over 850 000 American eels swam up the St. Lawrence River. That number has since plummeted by 98 per cent, troubling both commercial fishermen and environmental scientists.

It's mid-July, and American eels (*Anguilla rostrata*) swim up the eel ladder built across the Cornwall dam on the St. Lawrence River. The dam marks the finish line for their long trek from the Sargasso Sea, where they will eventually return to spawn and die.

Beyond the dam are frustrated commercial fishermen. Eight years ago, more than 850 000 eels climbed the ladder to stock the eel fishery of Lake Ontario. The numbers have since dropped by over 98 per cent. This year, less than 1 000 have succeeded in climbing the dam and there are reports of fewer commercial-sized eels.



photo by P. Hodson

The American eel (*Anguilla rostrata*)

Dr. Peter Hodson of NWRI's Rivers Research Branch is seeking to unravel the mystery. He is evaluating several proposed causes for the decline in eels, which include habitat destruction, chemical contamination, overfishing and oceanic climate change. But every clue seems to pose new questions, leading Dr. Hodson to suspect that a combination of factors may be at work.

Chemical contaminants

Deformities and periodic eel kills prompted Dr. Hodson to question pollution as a possible cause for the decline in eel numbers.

Surprisingly, his studies revealed that contaminant levels in eels have dropped significantly over the last decade. Only 36 per cent of the eels analyzed in 1990 exceeded fish guidelines for polychlorinated biphenyls (PCBs), as compared to 80 per cent in 1982. He also noted downward trends in mirex and other pesticides, except dieldrin. Concentrations of polynuclear aromatic hydrocarbons (PAHs), dioxins and furans were usually less than detection limits and well within all guidelines.

The results seem to rule out a contamination problem, but Dr. Hodson maintains that the decline in eels could be a delayed reaction to historic pollution. To understand the time delay requires a short course in the life history of the American eel.

From the time they are born in the Sargasso Sea until they are one year old, the juvenile eels are adapted to a marine environment. During this time they begin to migrate towards North American coastal streams. Towards the end of the first year, the eels begin to arrive; first in estuaries and then in freshwater. Between

their third and fourth year, the eels will pass the Cornwall dam and remain in freshwater lakes and streams for about 12 years. Between 12 and 16 years of age, the eels begin the long journey back to the Sargasso Sea to spawn in salt water. Compelled by the instinct to return home, the eels quit feeding and rely entirely on body fat for energy.

A very skinny eel finally arrives in the Sargasso Sea, and the contaminants that were once diluted in fat are now concentrated in muscle and eggs. This may reduce the fitness and survival of their offspring. If so, the decline in the current eel population may be partly due to pollution experienced by their parents during their sojourn in the Great Lakes/St. Lawrence Seaway prior to 1988 when contaminant levels were higher.

Multiple factors

While contaminants may play a role, they are probably not the sole cause of the eel problem. A single, concrete explanation to the eel mystery continues to elude researchers.

The Quebec Ministry of Recreational Fish and Game created a working group to help put together the pieces of the puzzle. The group includes Dr. Hodson and researchers from various agencies concerned about this commercially and ecologically important species. The scientists are pooling their knowledge to outline the research that will resolve the issue.

While at a European Inland Fisheries Advisory Commission meeting in Poland during May, Dr. Hodson remarked that the decline in the American eel parallels that of its close cousin, the European eel (*Anguilla anguilla*). American and European eels share spawning grounds in the Sargasso Sea, but migrate to different freshwater bodies to continue their life cycle. There is only one major difference in their mutual decline - the European eel population seems to have bottomed out, while the American eel continues to decline.

Coincidence? Maybe not. Other agencies are investigating whether a common element, such as oceanic temperature, may be affecting both populations. Dr. Hodson will investigate the combined effect of habitat destruction and chemical contaminants, with particular emphasis on the high dieldrin levels observed in his earlier studies.

Contact:

Dr. Peter Hodson

Reference:

Hodson, P., Castonguay, M., Couillard, C.M., Desjardins, C., Pelletier, E., and R. McCleod, 1992. Spatial and temporal variations in chemical contamination of American eels (*Anguilla rostrata*) captured in the estuary of the St. Lawrence River. *Canadian Journal of Fisheries and Aquatic Science*, (in press).

Empowering communities to help themselves:

Water tests a success in First Nations community

Most Canadians can turn on the tap without ever fearing for the quality of their water. But in isolated communities and developing countries, adequate drinking water quality monitoring is very difficult due to the scarcity of resources and technical expertise.

Environment Canada researchers formed part of a nine-country, four-continent study to develop practical, easy-to-use methods which empower communities to assess the quality of their own drinking water supplies. Using these methods, Environment Canada developed a prototype project with the Split Lake Cree First Nation in northern Manitoba to safeguard their water quality. The project fostered a significant improvement in community health and new laboratory facilities are being built by the Split Lake Cree First Nation to support their continued program.

The success of the Split Lake project has spurred interest in adapting similar programs for other remote First Nation communities in Canada. Furthermore, broad application of methods in less developed countries would substantially reduce the number of deaths attributed to water-borne diseases, estimated at over 30 000 per day globally. To this end,

the Split Lake community has agreed to assist in a similar pilot project for indigenous Chol-Chol Mapuche communities in Chile.

The Split Lake project is a noteworthy achievement for the two Environment Canada scientists who initiated the project. Barney Dutka of NWRI's Rivers Research Branch, and Peter Seidl, who now works for the International Joint Commission, first surveyed the quality of recreational and potable waters within several remote aboriginal communities in northern Manitoba in 1987. Their results led them to investigate the suitability of employing simple, inexpensive and rapid microbial water quality tests in northern Canadian waters. In 1990, the International Development Research Centre (IDRC) initiated a project to transfer this technology to the Split Lake Cree First Nation.

The researchers tailored the water testing procedures for use by untrained community members with minimal equipment and supplies. They also assisted the Split Lake community to become self-sufficient in monitoring and controlling the bacteriological quality of their drinking and recreational waters.

Dutka and Seidl recently completed a report describing the success of the Split Lake program and a methods manual. The Split Cree First Nation endorsed the report and submitted it as a final report to the IDRC. —

Contact:

Barney Dutka

References:

Seidl, P. and B.J. Dutka, 1993. Developing a self-sustained microbiological water quality testing capability in a remote aboriginal community. NWRI Contribution #93-124.

Dutka, B.J. and P. Seidl, 1993. Procedures for microbiological testing of drinking and recreational waters in remote and isolated communities. NWRI Contribution #93-129.

Scientists win federal information technology awards

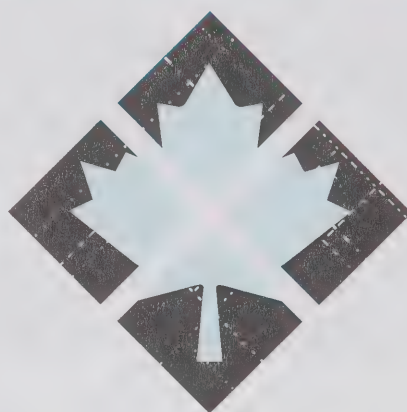
Two NWRI scientists walked away with gold and silver medals from the First Annual Celebration of Information Management Excellence in the Federal Government. The scientists were presented with their awards on September 13 at the Canadian Museum of Civilization in Hull, Quebec.

The awards program, organized by Treasury Board and the private sector, recognizes those extraordinary people who are managing, influencing and shaping the federal information systems arena. The two NWRI medals represent half of the awards received by Environment Canada under the 18 award categories.

Dr. David Lam Gold medalist

Dr. David Lam, International Programs Group, won a gold medal in the category of Technology Pioneers/Risk Takers. The award recognizes Dr. Lam's success in using information technology to improve the way that federal government does business.

The Regional Analysis by Intelligent Systems on a Microcomputer (RAISON) expert system is the brainchild of Dr. Lam. He recognized that commercial software is often inappropriate or



inadequate for the particular needs of environmental applications. His vision and insight led to the development of the RAISON software which merges environmentally relevant database technology with spreadsheet, graphics and modelling capabilities. The software continues to evolve and is now recognized as a unique piece of information technology in the global market place. Currently, Dr. Lam leads a team that is adding advanced features such as neural net technology and new database technologies.

Dr. Ed Ongley Silver medalist

Dr. Ed Ongley, Director of the International Programs Group, won a silver medal in the cat-

egory of Project Manager. This award is given to individuals who have adapted their role to excel in the new era of information technology. By winning the award, Dr. Ongley has demonstrated a well-rounded sense of mission, the ability to function effectively in teams from diverse backgrounds, exceptional business "savvy" and responsiveness to client needs.

Dr. Ongley has managed the RAISON program since 1986. In addition to providing a scientific climate for research and development, he is mainly responsible for negotiating contractual arrangements with clients from both inside and outside the federal government. Through the United Nations water program, he has provided international visibility for Environment Canada's information technology programs and secured significant market niches for RAISON. His efforts have closely linked Environment Canada with the private sector to enhance technology transfer and Canadian competitiveness overseas. —

Contact:

Dr. Ed Ongley
Dr. Dave Lam

NWRI

scientist elected as IAGLR president



Dr. Michael Zarull, Lakes Research Branch, was recently elected as president for the International Association of Great Lakes Research (IAGLR) for the 1993/1994 term.

Dr. Zarull's designation is a fitting tribute to his long involvement with the association and the Great Lakes. He presently serves as Great Lakes Officer to the Institute. He is heavily involved in the Great Lakes Remedial Action Plan program and recently co-edited the book *Under Raps*. Before coming to NWRI, Dr. Zarull worked for the International Joint Commission and the Ontario Ministry of the Environment.

Dr. Zarull is not the first NWRI scientist to hold this esteemed position. Since its inception in 1986, the Lakes Research Branch has been the source for three of the four Canadian IAGLR presidents, including Alena Mudroch and Dr. Klaus Kaiser.

Scientists gear up for capping test

Contaminated sediment is a major cleanup challenge at many Great Lakes areas of concern. Alex Zeman, Lakes Research Branch, leads a team of scientists who have designed a sediment capping demonstration project for Hamilton Harbour.

In a world of increasingly high-tech sediment treatment and removal techniques, capping represents a simple and inexpensive means to isolate contaminated, fine-grained sediments. The technique uses a layer of environmentally neutral material as a barrier between pollutants and the aquatic environment. The choice of capping material is dependent upon site conditions.

For Zeman, the demonstration

represents the culmination of years of research and design. It is scheduled to take place next year at a site off the harbour's north shore where bottom sediments exhibit intermediate to high acute toxicity. A 1 ha area will be covered with a layer of sand approximately 50 cm deep that should prevent metal and organic contaminants from being released into the water column. The scientists are currently monitoring conditions at the site to provide them with a "before" picture from which to measure the effectiveness of the technique.

The project is supported by the Cleanup Fund and is applicable to other Great Lakes areas of concern.

International symposium on municipal water treatment

The 1993 International Symposium on Chemistry and Biology of Municipal Water Treatment will be held at the Canada Centre for Inland Waters, October 24 - 29.

The symposium aims to upgrade the knowledge of producers, regulators and users of municipal water with respect to current treatment technologies and the rapid advances that are taking place in measurement, risk assessment and the legislative framework in Canada and abroad. It will review state-of-the-art technology and assess future trends in the drinking water industry.

The symposium, sponsored by the Chemical Institute of Canada, is designed to bring together chemists, chemical engineers, biologists, chemical technologists, managers and others who are involved in the drinking water industry. If you would like to attend the symposium, please call Dr. B.K. Afghan at (905) 336-4661.

Contact:

Alex Zeman

Reference:

Zeman, A.J., 1993. Subaqueous capping of very soft contaminated sediments. *Proceedings of the Fourth Canadian Conference on Marine Geotechnical Engineering, St. John's, Newfoundland* 2: 598-609.

Biological sediment guidelines

Reynoldson, T.B. and M.A. Zarull. 1993. An approach to the development of biological sediment guidelines. In: *Ecological Integrity and the Management of Ecosystems*. Woodley, S.J., Francis, G., and J. Kay, eds., St. Lucie Press, Delray Beach, Florida.

This paper describes an alternate approach to environmental decision-making using biological rather than chemical endpoints to determine both the need for and the success of sediment remediation and cleanup undertaken in Great Lakes areas of concern. It demonstrates the development and application of criteria, and possible implications on remediation costs.

Pulp mill tracers

Comba, M.E., V. Palabrica and K.L.E. Kaiser. 1993. Volatile halocarbons as tracers of pulp mill effluent plumes. NWRI Contribution #93-29.

This work uses volatile halocarbons in a pulp mill effluent, including chloroform, bromodichloromethane, tri- and tetrachloroethylene, as tracers for the distribution and movement of effluent currents in a receiving water bay on the north shore of Lake Superior. The results demonstrate the simplicity and usefulness of the technique and the significantly improved resolution of effluent plume delineation over conventional methods.



NWRI *Digest* is the public newsletter of the National Water Research Institute, Canada's largest freshwater research establishment. The Institute conducts a comprehensive program of research and development in the aquatic sciences which it undertakes in partnership with water management agencies and water science communities in Canada and around the world. Our research creates knowledge and develops expertise on water quality issues important for sustainable water resource use and the preservation of freshwater ecosystems.

Suggestions, comments and further enquiries concerning NWRI *Digest* are welcomed. Articles may be reprinted upon permission from the editor. Please write to:

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THE NEWSLETTER OF THE NATIONAL WATER RESEARCH INSTITUTE

Regional Round-Up

As a national institute, NWRI's research activities span the entire length and breadth of Canada — from the Agassiz Ice Cap on Ellesmere Island to the Fraser River in British Columbia to the Waterford River basin in Newfoundland.

This issue of *Digest* looks at a few of NWRI's activities in each of the five departmental regions of Canada. In an environmental sense, the boundaries between these regions are artificial — after all, global problems such as airborne toxic chemicals affect us all. NWRI activities provide a good example of how research done in partnership with the regions can have applications on a national (and sometimes international) scale.



PACIFIC & YUKON Developing biological guidelines for the Fraser River

The rise of the ecosystem approach to environmental management demands that scientists develop new "tools" that can measure ecosystem health and guide the path of environmental decision-making. Unfortunately, the chemical measures used successfully in the past to achieve gross reductions in environmental pollutants have proven singularly inadequate to the task of monitoring the inherent variability in biological systems.

NWRI scientists Drs. Trefor Reynoldson and Kristin Day are well known for their work on techniques that use *benthic invertebrates* to measure ecosystem health. They have found that these bottom-dwelling organisms are a useful monitoring tool because they integrate effects in sediments and the water column. With support from Environmental Protection- Ontario Region and the Cleanup Fund, the two scientists have developed biological sediment quality guidelines for the Laurentian



Environment
Canada

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Canada

Canada

Great Lakes that are based on a combination of toxicity testing and benthic invertebrate community structure monitoring. They will now be transferring this expertise to their next major research challenge—developing biological guidelines for the Fraser River Action Plan (FRAP).

The four-year project will:

- >> develop a network of reference and monitoring stations;
- >> identify appropriate variables to be measured (including toxicity tests to be used in conjunction with community structure analyses);
- >> identify key species for ongoing benthic community monitoring;
- >> outline a suitable monitoring strategy; and
- >> define numeric targets for interpreting the state of the Fraser River ecosystem.

Drs. Reynoldson and Day are developing the **Benthic Assessment of Sediment** computer model to help measure the need for, and the success of, remedial actions. The “BEAST”, as it is affectionately dubbed, is being devel-

oped with support by Environmental Protection-Ontario region and in conjunction with Dr. Dave Lam and researchers from the University of Western Ontario and the University of Canberra, Australia.

The “BEAST” measures the need for, and success of, remedial actions.

While originally designed for use in the Laurentian Great Lakes, Drs. Reynoldson and Day will be tailoring the model for use in the Fraser River. It will predict the characteristics of benthic communities at “clean” sites within the river and correlate this with toxicity tests that measure various stages of degradation from this state. Once FRAP decision-makers have defined how *clean* is *clean enough*, the model will provide them with numeric targets to aim for. —

Contact:

Dr. Trefor Reynoldson

Reference:

Reynoldson, T.B., Bailey, R.C., Day, K.E. and R.H. Norris, 1994. Biological guidelines for freshwater sediment based on Benthic Assessment of Sediment (the BEAST) using a multivariate approach for predicting biological state. *Submitted to the Australian Journal of Ecology*.

PRAIRES & NORTHERN NWRI scientists tackle problems in northern rivers

Stretching across three provinces and one territory, the Peace, Athabasca and Slave river basins together form one of the most prominent hydrological features in Canada. The rivers are essential to surrounding communities in the Northwest Territories and northern Alberta, where they are used for drinking water, recreation, transportation and fishing. Recent years have witnessed growing development pressures within the basins, especially with regard to a thriving forest industry. Public concern over the long-term, cumulative effects of these developments led to the creation of the Northern River Basins Study in 1991, led by Prairies and Northern Region.

Over the study's four year lifespan, NWRI scientists will help assess the effects of development on these systems by contributing to a database on water quality and the aquatic environment.

Contaminants

Dr. John Carey, Director of the Rivers Research Branch, draws upon his extensive background in pulp mill research to lead the Contaminants Component of the Northern River Basins Study. This component addresses concerns over the potential impact of pulp mill and industrial effluents on the aquatic ecosystem.

Northern River Basins Study

Research Components



Over the next two years, the scientists will:

- coordinate the activities of the Contaminants Working Group (Dr. Brian Brownlee);
- measure the biological toxicity of sediments to guide the development of ecosystem objectives (Drs. Kristin Day and Trefor Reynoldson);
- analyze historic patterns of contamination to differentiate between natural and industrial contaminant sources (Dr. Rick Bourbonniere); and
- investigate substances that trigger detoxification systems in fish and indicate exposure to pulp mill effluents (Drs. Peter Hodson, Kent Burnison, Bommanna Krishnappan).

Synthesis and Modelling

Dr. Brownlee also leads the Modelling Subcommittee of the Contaminants Component which is working on contaminant fate and food chain modelling. These results will help develop the means to determine present effects and predict future impacts of human development on the aquatic ecosystem.

This predictive capability requires a thorough understanding of the natural physical and chemical features within each of the basins. Sediment flocculation (or "clump-

ing") is one mechanism that largely influences contaminant transport. Dr. Krishnappan is studying flocculation in the Athabasca River, towards the ultimate goal of predicting the transport of contaminants in the aquatic ecosystem.

Hydraulics, Hydrology & Sediment

Drs. Krishnappan and Spyros Beltaos are also members of this component (led by Dr. Terry Prowse of the National Hydrology Research Institute) and provide advice on river hydraulics and ice jams.

Drinking Water Quality

Drinking water quality is not only a measure of public health. It also takes into account aesthetic values such as taste and odour. Dr. Brownlee is involved in a multi-agency investigation into odour compounds downstream of a pulp mill on the Athabasca River. A survey in March 1993 revealed that pulp mill odours were detectable in water retrieved 950 km downstream from a pulp mill at Hinton, Alberta. The survey has been repeated this winter to reveal if these odours persist following recent process changes at the mill.

Contact:

Dr. Brian Brownlee

impact of atmospheric pollutants on the Arctic ecosystem
effects of global warming and UV-B on northern aquatic ecosystems
evaporation and heat exchange on Quill Lake, Saskatchewan (part of the Heat, Evaporation and Mass Transfer Experiment)

ONTARIO

Climate change research program launched on Lake Erie

Lake Erie is the focus of a new NWRI research project aimed at predicting the impact of climate change on the quality of Canadian waters. The project forms one component of the Great Lakes-St. Lawrence Basin Project — a three-year, multi-agency assessment of the impact of climate variability and change in water management, land use management, and human/ecosystem health. This project is led by the Atmospheric Environment Service and funded under the federal Green Plan.

Why focus on Lake Erie? There are several reasons. Erie is the shallowest of the five Great Lakes and, consequently, its physical, chemical and biological components are very sensitive to changes in weather and climate. The lake also has a history of environmental problems (e.g., hypolimnetic anoxia, excessive algae and cladophora growth, zebra mussel invasion, etc.) that may be influenced by climate. Finally, Lake Erie is an invaluable economic and recreational resource, and as such, any lakewide changes would have widespread socioeconomic ramifications.

William Schertzer, Lakes Research Branch, heads the scientific team looking into adaptive strategies for climate-related changes in Lake Erie water quality.

Schertzer and his colleagues will use NWRI's Water Quality Model for Lake Erie and roughly 40 years of monitoring data to describe the physical and water quality conditions of the lake (e.g., water temperature, thermal stratification, nutrient conditions, dissolved oxygen concentrations, etc.) under current levels of atmospheric carbon dioxide and heat fluxes. The model will then be used to recalculate these conditions based on climate scenarios derived from the Canada Climate Centre's Global Climate Model II.

The model's results will be used by other government agencies to predict the socioeconomic impacts of climate change, including its effects on Great Lakes sport and commercial fisheries, the quality and availability of drinking water, and recreational uses. Ultimately, the team will formulate adaptive strategies to deal with these upcoming changes.

Contact:
W. Schertzer

Reference:
Schertzer, W.M. and A.M. Sawchuk, 1990. Thermal structure of the lower Great Lakes in a warm year: Implications for the occurrences of hypolimnion anoxia. *Transactions of the American Fisheries Society* **119**: 195-209.

QUEBEC

Searching for links between contaminants and belugas

The St. Lawrence estuary and adjacent waters of the Gulf of the St. Lawrence are home to a small, isolated colony of beluga whales (*Delphinapterus leucas*). Commercial hunting earlier in the century reduced the numbers of these placid white giants to a few hundred animals — a trauma

from which they have never really recovered. The prevailing theory holds that contaminants from the Great Lakes/St. Lawrence system, such as mercury, lead, polychlorinated biphenyls (PCBs), mirex and dichlorodiphenyl trichloroethane (DDT), may be responsible for this delayed recovery. If

so, then it is important to understand where these chemical sources originate, how they behave in the ecosystem and how their effects can be mitigated.

Unfortunately, little was known about the sources, fate and transport of organic contaminants in the St. Lawrence River prior to 1985. The impact of Lake Ontario (the main hydrodynamic force accounting for 60 per cent of the river's flow) was thought to be minimal since most contaminants were expected to settle to the lake bottom before reaching the estuary.

But in 1985, Lakes Research Branch scientists Mike Comba and Dr. Klaus Kaiser made a disturbing discovery. The scientists were working in collaboration with staff from the National Wildlife Research Centre to develop a mass budget for mirex — a pesticide and fire retardant that was manufactured in Niagara Falls prior to 1976. The scientists determined that roughly 25 per cent of mirex in Lake Ontario had been transported down the St. Lawrence River. In fact, mirex was detected as far away as the Laurentian Trough, some 1500 km downstream from its major source in the Niagara River!

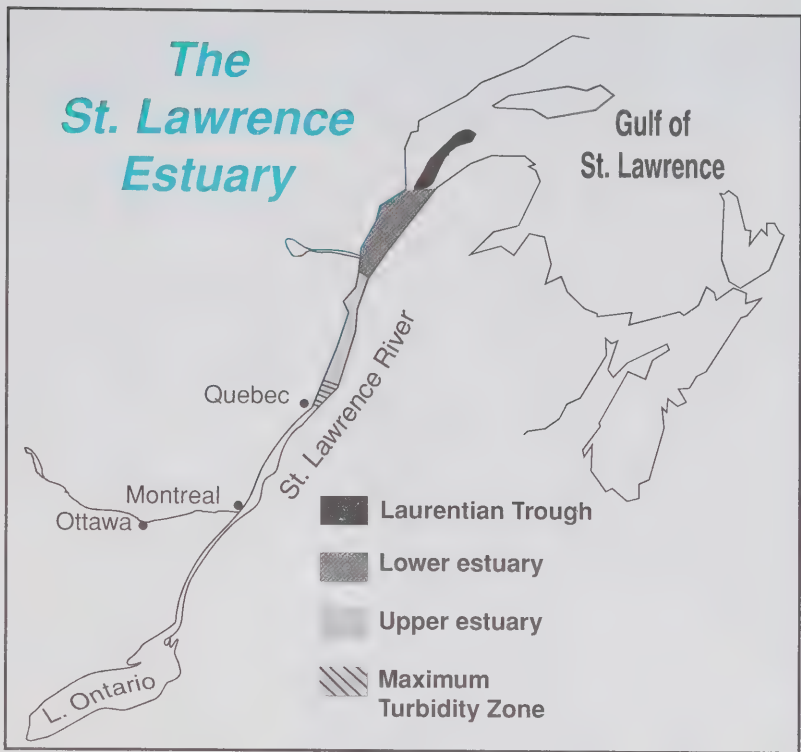
This discovery led to an investigation into the processes that govern contaminant fate and interactions in the Great Lakes/St. Lawrence ecosystem. The scientists found that most organochlorine contaminants spend less than five years in the St. Lawrence River before being flushed into the Gulf of St. Lawrence. Their calculations also revealed that contaminant loadings to the River from Lake Ontario have dropped by 30 to 90 per cent between 1985 and 1990. If contaminants are slowing the recovery of the beluga whales, then this may be a good sign for their long-term stability. However, while Lake Ontario is the *main* source of water for the St. Lawrence, it is not necessarily the *only* source of contaminants to the estuary. In fact, overall contaminant loadings of chlordane

and DDT showed no distinct tendency toward lowered inputs.

How are these contaminants entering the food chain? Previously, scientists believed that the upper St. Lawrence estuary could be a sink for contaminants. In this area, a dense, salt water "wedge" intruding from the Atlantic Ocean encounters the river water, creating a zone of high turbidity where fine sediments (and their associated contaminants) are trapped and resuspended in the water column.

However, a study by Lakes Research Branch scientists Drs. John Coakley and Elmer Nagy showed that the upper estuary doesn't "trap" the sediments (and their associated contaminants) for very long. Working in partnership with researchers from Laval University, they found that the oldest sediments in the upper estuary were still less than 35 years old and were relatively less contaminated than sediments upstream in Lake Ontario and Lac Saint-Pierre. Instead of remaining in the upper estuary, the majority of the sediments are apparently flushed out at regular intervals and transported to the Gulf of St. Lawrence.

Scientific attention has now turned to the highly productive lower estuary near the Laurentian Trough. Contaminant concen-



> impact of acid rain on sensitive aquatic ecosystems
 > occurrence of textile dyes, PCBs and pesticides in the Yamaska River
 > impacts and causes of eel declines in the St. Lawrence River basin
 > effects of frazil ice on hydroelectric generation

Groundwater research, including: 1) analysis of naturally occurring manganese contamination in the Fredericton aquifer, New Brunswick; 2) the study of pesticide contamination of groundwater beneath potato fields in P.E.I.; and 3) development of a formal agreement with University of New Brunswick to foster groundwater research in the Maritime provinces

trations are low in this area as well; however, the estuarine food chain seems to be extremely effective at scavenging nutrients and contaminants from the water. Comba and Dr. Kaiser found bioaccumulation factors of mirex in fish at 10^5 and in belugas at 10^8 . In other words, the concentration of some contaminants in belugas were up to 100 million times that of water. The scientists will soon be analyzing contaminant data from the lower estuary to reveal possible mechanisms for the entrance of these contaminants in the food chain.

These studies, over almost a decade, are a part of NWRI's continuing contribution to the St. Lawrence Action Plan under leadership of Environment Canada's Quebec Region.

Contact:

Dr. John Coakley
Mike Comba
Dr. Klaus Kaiser

References:

Comba, M.E., Norstrom, R.J., Macdonald, C.R. and K.L.E. Kaiser, 1993. A Lake Ontario-Gulf of the St. Lawrence Dynamic Mass Budget for Mirex. *Environmental Science and Technology* **27(10)**: 2198-2206.

Comba, M.E., Palabrica, V.S., Backus, S.M. and K.L.E. Kaiser, 1993. St. Lawrence River Trace Organic Contaminants Study, Part IV, 1989-1990 and Summary. NWRI Contribution 93-19.

Coakley, J.P., Nagy, E. and J.-B. Sérodes, 1993. Spatial and vertical trends in sediment-phase contaminants in the upper estuary of the St. Lawrence River. *Estuaries*, **16(3B)**: 653-669.

ATLANTIC

Ice jam information summarized


River ice jams have a variety of social, economic and environmental impacts. Flooding, damage to structures, interference with navigation and hydro-power production occur in Canada each winter and spring, causing losses of \$50 to 100 million annually. Moreover, ice jams are an important factor in ecosystem balance. Changes to the ice jamming regime of a river may have serious ecological implications. Atlantic Canada is perhaps the most seriously affected region in the country, owing to a combination of hydrologic, climatic and demographic factors that increase the frequency and impact of ice jams. The Saint John River is a famous case in point.

Until recently, ice jams were regarded as natural events that must be passively endured. In the past few decades, however, research and engineering have contributed greatly to our understanding of these events. While there are still unknowns, many ice-jam related problems can now be solved or mitigated. However, relevant information is scattered in many different sources, such as journals, reports and conference proceedings.

To remedy this situation, the Canadian Committee on River Ice Processes and the

Environment sponsored the preparation of a monograph to consolidate current knowledge on ice jams. The monograph was produced through a Working Group, chaired by Dr. Spyros Beltaos of NWRI's Rivers Research Branch.

The nine chapters of the monograph provide complete coverage on various issues, such as the impact of ice jams throughout Canada, river ice and jamming processes, theoretical developments, numerical and physical modelling, mitigation methods, case studies, and field data collection requirements and methods. Dr. Beltaos edited the monograph and authored two of the chapters.

In the future, the focus of NWRI research on ice jams will expand to include research into the potential effects of climate warming on river ice and implications for ecosystem management. 

Contact:

Dr. Spyros Beltaos

References:

Beltaos, S., 1994. *River Ice Jams* (in press).

Beltaos, S., 1988. *Monograph on River Ice Jams*. Chapter 3: Ice Jam Processes; and Chapter 4: Theory. NWRI Contribution 88-50.

National Lab merges with NWRI

As of April 1, 1994, the National Laboratory for Environmental Testing (NLET) is an official member of the NWRI team — adding analytical “firepower” to the Institute’s aquatic ecosystem research.

NLET is one of a group of Environment Canada’s laboratories that provide critical scientific measurements in support of departmental programs. With a staff of 40 professional and technical personnel, NLET offers a broad range of analytical testing capabilities.

NLET’s modern facilities, located at the Canada Centre for Inland Waters, house an arsenal of sophisticated instrumentation capable of providing reliable measurements to extremely low levels of detection. Tests range from traditional lake chemistry characterization to ultra-trace measurement of toxic metals and organic contaminants in waters, sediments and tissues. The work of NLET supports the department’s programs in all five regions, with limited services being extended to other government departments on a cost-recovery basis.

With the advent of competitive private sector analytical capability, the role of NLET and other governmental laboratories has evolved considerably. The labs are aggressively networked to provide a powerful tool to help deliver sound and credible science. This entails development and testing of new analytical

procedures in anticipation of emerging issues and transfer of the new capability into the private sector. It reflects a subtle shift from being the provider of data to ensuring data contributed in support of departmental science meets appropriate federal standards.

Successful science cannot be achieved in isolation. NLET maintains vigorous and productive ties with laboratories in the departmental network, Canadian universities, the private sector, the U.S. Environmental Protection Agency and the U.S. Geological Survey. This fosters teamwork in delivering sound scientific data and allows the federal laboratory to influence external programs. The new or-

ganizational link to the NWRI will further enhance these objectives and activities.

NLET houses an arsenal of sophisticated instrumentation capable of providing reliable measurements to extremely low levels of detection.

NLET is currently organized into three sections. The main body of staff forms the Analytical Chemistry Section, responsible primarily for providing the measurements. The Program Development and Operational Support Section provides objective quality management, total informatics support, and fulfils the complex and demanding client

liaison functions. The Research Support and Methods Section bridges the gap between research and operational program delivery. Together, these sections become the operational science arm of NWRI.

Contact:
Robin Sampson
Director, NLET

Scientist Wins Sverdrup Award

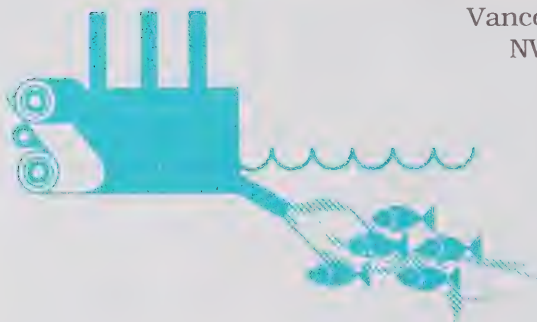
Dr. Mark Donelan, Research and Applications Branch, has been named the 1994 recipient of the American Meteorological Society’s Sverdrup Gold Medal Award. Dr. Donelan received the medal on January 26 at the annual meeting of the American Meteorological Society in Nashville, Tennessee.

The Sverdrup Gold Medal is granted to researchers who make outstanding contributions to the scientific knowledge of interactions between the oceans and the atmosphere. The award recognizes Dr. Donelan’s “numerous contributions to the understanding of the physics of ocean surface waves.”

CALL FOR ABSTRACTS

2nd International Conference on Environmental Fate and Effects of Bleached Pulp Mill Effluents

The 2nd International Conference on Environmental Fate and Effects of Bleached Pulp Effluents will be held at the Hotel Vancouver in Vancouver, British Columbia, from November 6 to 10, 1994. This NWRI-sponsored conference will discuss the progress in evaluation techniques, the impacts of new technologies, field and laboratory investigations, and the anticipated impacts of future developments within the industry.



All platform presentations and posters must submit an abstract before May 15, 1994. For more information, please contact Dr. Kelly Munkittrick, GLLFAS, Department of Fisheries and Oceans, P.O. Box 5050, Burlington, Ontario L7R 4A6. Tel: 905-336-4864, fax: 905-336-6437.



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THE NEWSLETTER OF THE NATIONAL WATER RESEARCH INSTITUTE

***"Progress is impossible without change;
and those who cannot change their minds
cannot change anything."***

— **George Bernard Shaw**

As part of the strategic response of the Ecosystem Conservation Directorate to Environment Canada's new corporate directions, NWRI has just undergone a major restructuring. The initial step has been the merging of the National Laboratory for Environmental Testing (NLET) with NWRI. This merger will strengthen the science contributions to NWRI's partnerships with the regions in delivering the "flagships" and other priority programs. It will also permit greater efficiency in the transfer of analytical services and methods development within Environment Canada.

NWRI had been organized into flexible, multidisciplinary, issue-based research projects seven years ago. However, to effectively align our aquatic ecosystem R&D with the Department's longer-term requirements for sustainable develop-

ment, research priorities had to be redirected. The new projects represent a balancing of many factors, including critical mass for new priorities, skills mix, compatibility of expertise, opportunities for redirecting staff research, and the potential for research partnerships and revenue generation. As described later in this issue, the new projects have been grouped into four branches based on program themes and workload balance.

Initial reaction to the realignment has been very positive. Research effort on emerging issues, such as ecological effects of increased UVB, persistent toxic substances and climate change, has been intensified, while the R&D focus of long-standing issues, such as Great Lakes water quality, has been sharpened. I am confident that the new structure will strengthen NWRI's contribution to the sustainable development goals of Environment Canada.

R.J. Daley
Executive Director



Aquatic Ecosystem Conservation Branch

The Aquatic Ecosystem Conservation Branch (AECB) conducts research on methods to conserve the health and sustainability of aquatic ecosystems. Its main activities include:

- assessing changes in aquatic ecosystems resulting from stressors ranging in scale from point source discharges to global scale changes;
- developing early warning indicators of ecosystem change;
- producing information concerning the sources of ecosystem impacts and the information base upon which mitigative measures can be developed; and
- developing new approaches and methods for assessing aquatic ecosystem health and establishing ecosystem objectives.

AECB is organized into three distinct projects: **River Basin Impacts**, **Atmospheric Change Impacts** and **Ecosystem Health Assessment**.

River Basin Impacts

What are the ecosystem level effects occurring as a result of atmospherically transported contaminants? What is the rate at which changes are occurring? What will be the magnitude of the changes should no management occur? How can contaminant sources be identified? How fast and to what extent will the system respond to control actions?

This project conducts research into the basin-scale effects resulting from the atmospheric transport of contaminants. Since these stressors often originate far from their sites of impact, the results of this research are important in providing the knowledge necessary to undertake multi-lateral negotiations and reach agreement for appropriate corrective actions. Research focusses on regional ecosystem scale with significant LRTAP-related activities across Canada, particularly in eastern Canada and the Arctic.

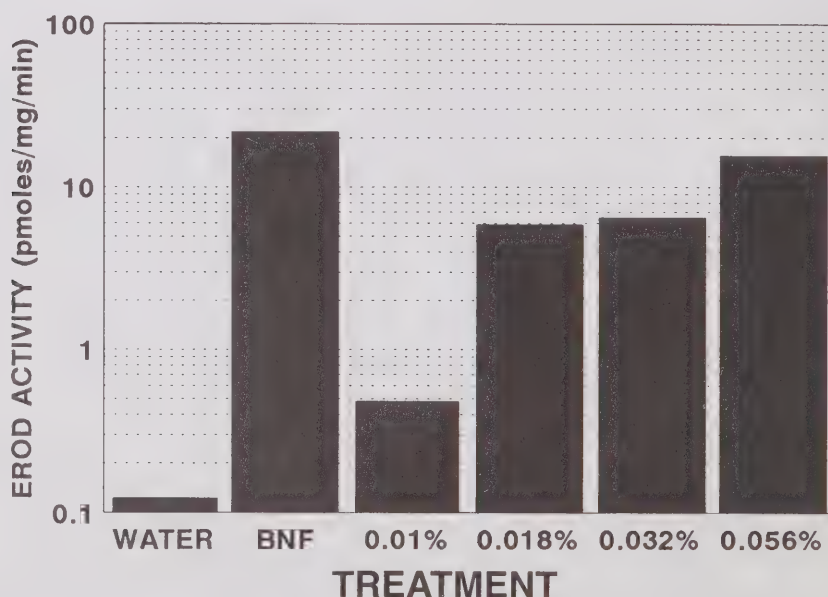
Atmospheric Change Impacts

What are the aquatic impacts of UV-B increases and global climate change? How can the sources be controlled? Can strategies be developed to minimize the extent of impacts on Canadian ecosystems prior to full-scale international controls?

This project assesses the nature and extent of global-scale changes such as climate change and ozone depletion on aquatic ecosystems. It focusses on sustainability of aquatic ecosystems and aquatic effects of climate change and UV-B in the face of anticipated atmospheric changes resulting from fossil fuel combustion, chlorinated solvent release and other human activities.

BLACK LIQUOR DILUTION CURVE

Rainbow trout liver enzymes (EROD activity) increase with exposure to various concentrations of black liquor. Normal enzyme levels (water) are low and increase in response to inducing chemicals such as B-naphthoflavone (BNF). Exposure to black liquor from a pulp mill causes a similar increase in enzymes.



Ecosystem Health Assessment

How can the effect of human activities be identified at the ecosystem level? What are the appropriate indicators for assessing ecosystem health? How can they be used to develop aquatic ecosystem objectives?

This project assesses the health, structure and function of aquatic ecosystems impacted by local human

activities. In co-operation with other agencies, it contributes to major conservation issues such as sustainable forestry. The focus is on (i) methods of conserving biodiversity, (ii) identifying and controlling the aquatic impacts of nationally important industries, and (iii) developing indicators of ecosystem health and function for use in national programs.

Aquatic Ecosystem Protection Branch

Photo: Jiri Marsalek



Overall view of the Kingston Township stormwater management pond

The Aquatic Ecosystem Protection Branch (AEPB) develops detailed knowledge and understanding of the behaviour and impacts of priority pollutants to support informed environmental decision making and sustainable management practices. Studies focus on chemicals that are identified as priorities under the *Canadian Environmental Protection Act (CEPA)* and the *Pest Control Products Act (PCPA)*. A strong emphasis is also placed on regional “flagships” (e.g., Great Lakes 2000, Fraser River Action Plan and Northern River Basins Study), pollution prevention and ecosystem sustainability.

AEPB is composed of three projects: **Priority Substances, Contaminant Pathways and Controls**, and **Environmental Standards and Statistics**. Activities include:

- identifying patterns of behaviour of priority toxic substances in aquatic environments;
- providing information for Priority Substance List assessments under *CEPA*;
- assessing the impact of non-point source pollutants on aquatic ecosystems;
- determining the role of suspended sediment in the riverine transport of toxic substances;

- ensuring the integrity of environmental data by implementing appropriate analytical quality control; and
- enhancing interpretive information through the use of statistics and environmetrics.

Priority Substances

What are the sources, pathways, fate and effects of priority toxic substances in aquatic ecosystems?

This project provides strategic knowledge and expert advice on the behaviour of toxic chemicals in the environment. Emphasis is placed on providing appropriate scientific information to support environmental decision-making under (i) *CEPA* and *PCPA*, (ii) virtual elimination, (iii) pollution prevention, (iv) sustainable development, and (v) ecosystem indicators.

Contaminant Pathways and Controls

How do chemical pollutants from non-point sources migrate through the aquatic environment? What are their impacts on the ecosystem? What control options exist?

This project conducts research and develops sustainable strategies for aquatic ecosystems subject to non-point source agricultural, forestry, industrial and urban stressors. Research focusses on (i) generating ecosystem-based knowledge of non-point sources of water pollution, (ii) understanding its behaviour and impacts on riverine ecosystems, and (iii) developing management measures for preventing and remediating these impacts.

Environmental Standards and Statistics

What statistical approaches and quality management measures should be incorporated into data collection

to ensure that regulatory and other end-user requirements are met? How can environmetrics be used to enhance the interpretation of environmental data sets?

This project helps to ensure that meaningful and reliable environmental data are collected for effective and economic regulatory compliance monitoring, impact assessments, trend monitoring and research. The focus is on water quality management support to (i) flagship programs, (ii) federal/provincial water quality agreements, (iii) acid rain programs, and (iv) CEPA regulatory requirements.

Aquatic Ecosystem Restoration Branch

The Aquatic Ecosystem Restoration Branch (AERB) provides the knowledge necessary to restore degraded ecosystems to a level that can be permanently sustained through conservation and protection. Restoration can occur naturally, but often nature needs a helping hand to reduce ecological stressors such as high contaminant levels or poor management practices. AERB assesses degraded aquatic ecosystems to support decisions on control measures to determine the extent to which nature can be relied upon to clean itself.

AERB is broken down into three projects: **Groundwater Remediation**, **Lake Remediation** and **Sediment Remediation**. Activities include:

- assessing aquatic ecosystem health, stability and sustainability;
- creating indicators of ecosystem health and recovery;
- devising water quality, ecosystem health and sustainability objectives and guidelines;
- producing information for State of the Environment reports; and
- originating, proposing and implementing mitigation measures or remedial techniques at degraded sites.

Groundwater Remediation

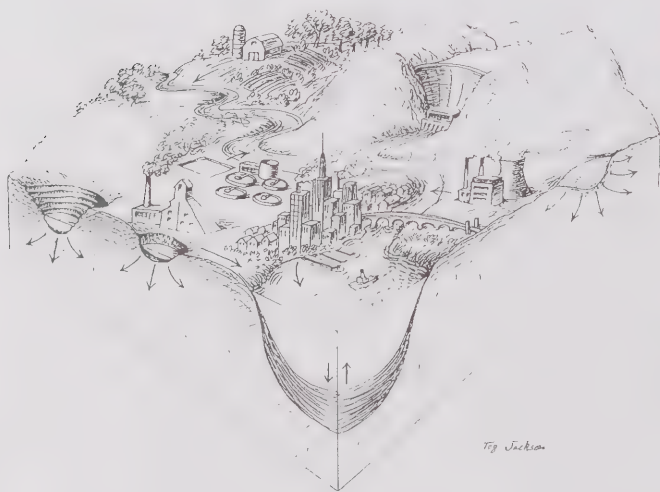
What are the impacts of human activity on Canadian groundwater? How can these effects be remediated?

This project conducts research to assess and remediate degraded groundwater. Activities are focussed on (i) federally owned sites, (ii) sites with transboundary international and inter-provincial degradation, and (iii) sites where federal research assistance is sought.

Lake Remediation

What is the health of specific lake ecosystems and related bodies of water? What causes the degradation? What remediation and restoration options exist? How can we track progress towards ecosystem health and sustainability goals?

This project conducts research to assess and remediate lake ecosystems, with emphasis on (i) developing and implementing Remedial Action Plans for the Great Lakes' Areas of Concern, (ii) Lake Management Plans for the lower lakes Erie and Ontario, and (iii) sustainable development in the Great Lakes basin in general.



Schematic drawing of hypothetical landscape showing various sources of contamination and other causes of environmental degradation (open pit mine, underground mine, tailings pond, smelter, sewage treatment plant, landfill or dump site, reservoir, dam, and electric power station). Arrows indicate routes of contaminant transport and migration into surface water sediments and groundwater.

Sediment Remediation

What are the effects of sediment-associated contaminants in aquatic ecosystems and how can these effects be controlled, mitigated or remediated?

This project assesses methods for remediating degraded sediments in aquatic ecosystems. The degradation of

sediments may be ongoing or historical and related to a variety of activities such as steel making, pesticide use, sewage disposal and mining activities. Emphasis is placed on highly stressed sites, such as those located adjacent to major industries.

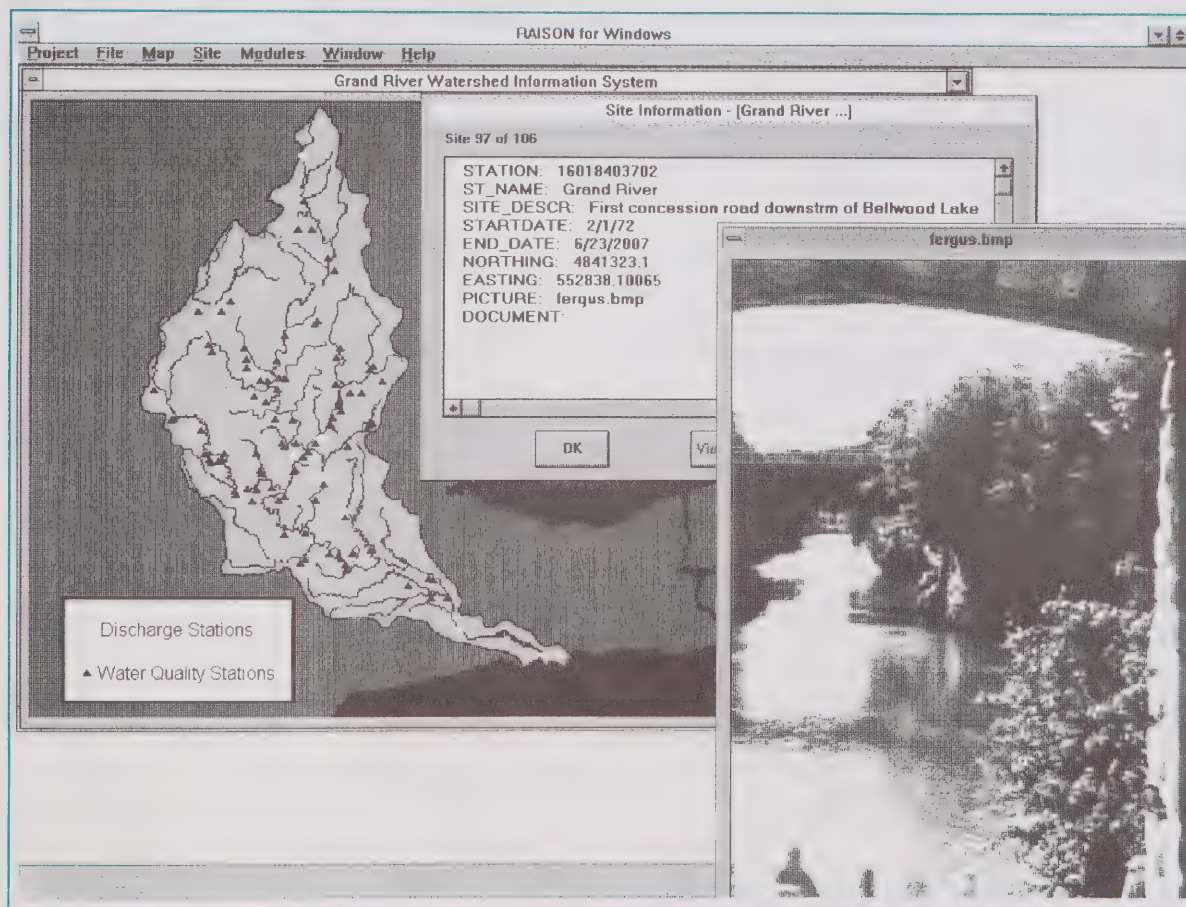
New Technologies Research Branch

In cooperation with outside partners, the New Technologies Research Branch (NTRB) investigates selected new technologies that are critical to Environment Canada's priorities and which have far-reaching value to Canadian competitiveness in the international marketplace.

NTRB is composed of three projects: **Environmental Information Technology**, **Aquatic Remediation Technologies** and the **GEMS/Water Collaborating Centre**.

Activities include:

- researching new technologies;
- coordinating technology transfer and intellectual property;
- delivering Environment Canada's commitment to the United Nations Environment Programme's Global Environmental Monitoring System for Freshwater (UNEP GEMS/Water); and
- enhancing Canadian competitiveness.



Display: D.C.L. Lam

Example from the RAISON/WINDOWS system for the Grand River Watershed Study undertaken in cooperation with the University of Waterloo Tri-Council Eco-Research Project. From left, a map of the watershed showing discharge and water quality stations, information about a selected site, and a photograph of the site.

Environmental Information Technology

In this communication age, Environment Canada will be judged by its ability to collect, integrate, interpret and disseminate complex environmental information. Research within this project focusses primarily on decision-support capabilities using knowledge-based systems and neural network technologies. These bring physico-chemical and socio-economic sciences together in order to simplify the task of developing policy options and of managing complex environmental issues.

The RAISON family of environmental information (EI) products is part of a global information technology (IT) market estimated at one to two trillion dollars. RAISON is now being distributed worldwide under licence by the UN water program and has achieved visibility in a large market audience in Latin America, Europe and Asia. NWRI has joined forces in a university and industry partnership to develop next-generation EI technologies for use within the department and for export. RAISON technology is a central component of a basin management software being produced by the University of Waterloo.

Aquatic Remediation Technologies

Dredging of contaminated sediments from harbours, lakes and rivers carries environmental risks. It is now so

expensive that public agencies are looking for more cost-effective alternatives. Research within this project focusses on enhancing natural remediation processes to reduce the toxicity of highly contaminated bottom sediments and avoid the need for dredging. Research is also carried out to improve the understanding of the importance of the role of sediments and particulate matter in the transport and fate of environmental contaminants in aquatic ecosystems.

GEMS/Water Collaborating Centre

In much of the world, freshwater has become the key limiting factor for sustainable development. Canada assists the global effort through NWRI serving as a UNEP Collaborating Centre for the implementation of GEMS/Water. NWRI has prime responsibility for the operation and maintenance of the global data base developed from water quality monitoring data submitted by countries participating in the GEMS/Water programme. NWRI also plays a lead role in the implementation of GEMS/Water in Latin America, Asia and the Pacific. Other activities under this project include (i) provision of scientific advice and assistance to various UN agencies active in water-related programmes and (ii) representation of the GEMS/Water programme at international meetings.

National Laboratory for Environmental Testing

The National Laboratory for Environmental Testing (NLET) contributes to the development and application of sound, science-based knowledge for balanced and effective ecosystem management. In short, this involves providing chemical and biological measurements in support of a range of departmental programs and projects. NLET operates within the confines of a departmentally defined role — a unique niche — appropriate to a public sector laboratory. It responds to the question, «How can one ensure science-based activities are adequately and effectively supported with reliable information derived from environmental measurements?»

To fulfil its mission and role, NLET is organized into three discrete sections: **Program Development and Operational Support, Research Support and Methods Development, and Analytical Chemistry.**

NLET's main activities include:

- participating in program planning for client groups, particularly in the development of data quality ob-

jectives, and managing contracted analytical services on behalf of client agencies;

- developing analytical techniques and associated performance-based specifications for reliable, cost-effective measurements in support of client testing requirements;
- maintaining adequate in-house capability to ensure programs meet required quality standards;
- assisting client groups through on-site support for field activities and data interpretation;
- providing expert testimony in litigations resulting from departmental regulatory activities;
- networking within the departments while accessing the full range of measurement services available nationally;
- developing and exporting measurement technologies to private sector laboratories; and
- supporting and promoting the Canadian Association of Environmental Analytical Laboratories (CAEAL) to strengthen the environmental laboratory industry.

Program Development and Operational Support (PDOS)

PDOS provides client management support, including project planning, resource allocation and related liaison services, covering a range of activities essential to ensure NLET outputs serve the intended purpose. It also dispenses management services to NLET such as an objective assessment of performance and efficacy of corrective actions for identified deficiencies. PDOS manages all informatics activities, including the development and maintenance of a modern responsive laboratory information management system (LIMS).

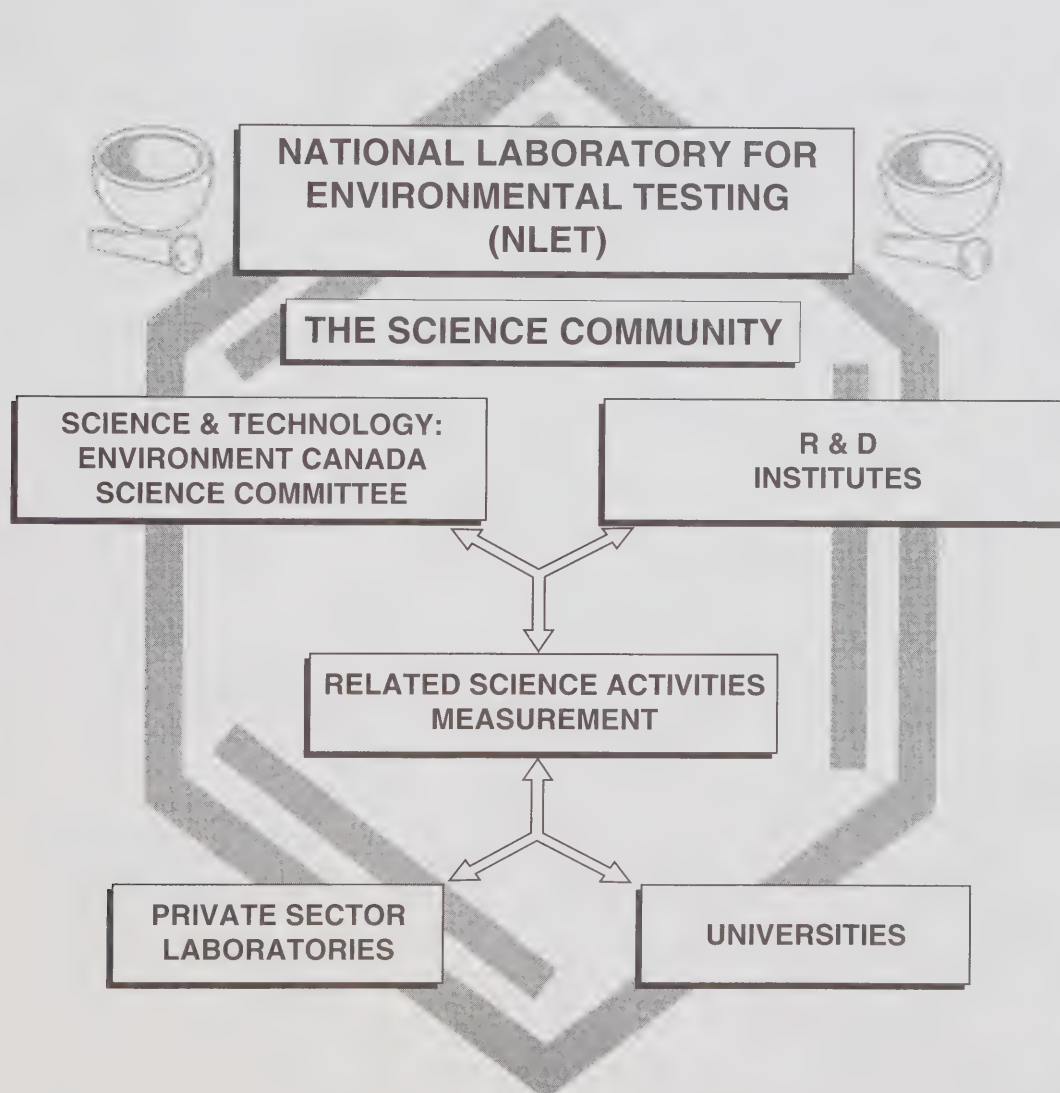
Research Support and Methods Development

This project bridges the technology transfer gap between the R&D stage and the operational utility in a production environment as well as between the federal laboratory and the private sector laboratory. Recognizing that education plays a fundamental role in research, the project also nourishes ties with academic institutions on

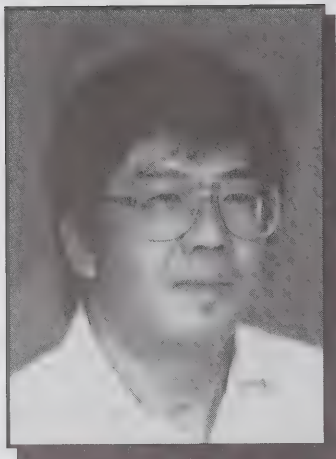
a continuing basis to promote technology and information interchange. It also ensures that NLET maintains the "leading edge" of technological capability, positioning the laboratory to respond effectively to tomorrow's problems rather than remaining focussed on those of yesterday.

Analytical Chemistry

This group makes up the heart of NLET, providing a broad range of high quality measurement capability to client agencies. It carries out inorganic and organic chemical testing for a broad range of constituents in waters, sediments and tissue, while using a comprehensive program of quality control, assurance and assessment to ensure that measurements meet prescribed specifications. The project also develops and tests laboratory protocols, standard operating procedures, and methods of analysis and quality control. It also maintains ongoing accreditation through an external adjudicator (CAEAL).



OBITUARY / Alfred S.Y. Chau



Alfred S.Y. Chau, Chief, Quality Assurance Project, Research and Applications Branch, National Water Research Institute, Canada Centre for Inland Waters, passed away in Burlington on May 24, 1994. He was 52.

Born in Hong Kong, Mr. Chau came to Canada in 1958 to study at the University of British Columbia. After receiving his M.Sc. from Carleton University, he worked as a pesticide residue chemist for Agriculture Canada before joining Environment Canada in Burlington in 1970.

Respect for Alfred Chau's work was global. He chaired international conferences, authored four books and over 100 papers, and his name appeared in 23 books of international recognition. These included *Who's Who in the World*, *Personalities of Americas*, *International Who's Who of Contemporary Achievement* and *International Who's Who of Intellectuals*.

Mr. Chau was also a nationally acclaimed wildlife artist. His paintings of wildlife in natural settings are in many collections, including the Dofasco Canadian Art Collection, Carleton University and the Hiram Walker Art Collection.

Mr. Chau, known by his friends as Alfie, is survived by his wife Linda, his son Andrew, his mother Sue Chong Chau and his brother Douglas Chau of Calgary.



NWRI *Digest* is the public newsletter of the National Water Research Institute, Canada's largest freshwater research establishment. The Institute conducts a comprehensive program of research and development in the aquatic sciences which it undertakes in partnership with water management agencies and water science communities in Canada and around the world. Our research creates knowledge and develops expertise on water quality issues important for sustainable water resource use and the preservation of freshwater ecosystems.

Suggestions, comments and further inquiries concerning NWRI *Digest* are welcomed. Articles may be reprinted upon permission from the editor. Please write to:

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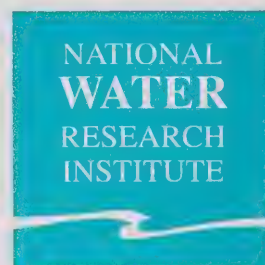
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Lake Erie: Toward Sustainability

Lake Erie first came to the attention of the media some thirty years ago with dramatic headlines like "Lake Erie is dead." Intensive research at CCIW in the sixties and seventies identified a phosphorus loading problem that spawned excess algal growth and threatened the Lake Erie fishery. A link between research and policy led to the 1972 *Canada/U.S. Great Lakes Water Quality Agreement*, advocating actions that in turn successfully reversed the trend towards increased phosphorus loadings. Through the resulting phosphorus reduction, the world's largest commercial freshwater fishery was established in Lake Erie.

In issue 18 of the *Digest*, published in the summer of 1993, we highlighted the emerging problem of the zebra mussel invasion of Lake Erie. In this article we reported on the proliferation of zebra mussels which occurred in the late eighties, probably as a result of the discharge of ballast water from a transoceanic vessel in Lake St. Clair in 1986. Other studies showed that by 1990 this species had colonized most hard surfaces in the lake. Fortunately, fish were still available then. Perhaps surprisingly, walleye continued to spawn on shoals with mussel concentrations as high as 200,000 per square metre. Evidence from core-research undertaken at CCIW, however, was warning of possible pronounced changes to the ecosystem—namely effects of zebra mussels on fate of contaminants, nutrients and oxygen, and alterations in species composition. Furthermore a second related species, the "quagga mussel," had also emerged on the scene.

The intent of this special Lake Erie issue of the *Digest* is to highlight our approach to clarifying current zebra mussel effect on the ecosystem and our ability to predict their future impacts. The articles also provide an opportunity to introduce some of NWRI's partners and report on the results that are becoming evident. The Lake Erie initiative is very

interesting
in itself as a
successful, practical
application of multidisci-

plinary ecosystem research in the pursuit of solutions to secure sustainability of an ecosystem. The articles demonstrate how multidisciplinary teams and consortia have bridged the gaps among agencies and between sectors — government and university — to undertake complementary research towards a common goal: a sustainable Lake Erie. Space constraints have limited the number of stories — there is much more to tell. Plans are in place to collect further information this year and combine forces to resolve this ecosystem puzzle. ➤

Janet K. Cooley
Editor



Lake Erie Fishery

113 active boats over 40'
500 occupational fishers
landed value of \$27,545,000
exports ≈ 65%
total estimated value = \$105.7 million



Changes to Nutrient and Contaminant Cycling

Murray Charlton of the Lake Remediation Project (Aquatic Ecosystem Restoration Branch) has collaborated with federal government scientists and university researchers, particularly GLURF recipients, to ascertain changes in nutrient and contaminant cycling that are attributable to the preponderance of zebra mussels. During the recent field season, Charlton's team have undertaken six water quality surveys of three basins, in cooperation with IWD Ontario Region and DFO. The survey results will be compared with earlier data to determine recent lake changes. A report describing nutrients, chlorophyll and water transparency in the lake in 1994 will then be prepared and used in the development of the Lake Erie Lakewide Management Plan (LaMP).


Charlton deployed sediment traps at four sites in each of the three basins. The sediment

traps will be collected this year and will provide a means to compare current fluxes in organic matter with those determined by Charlton prior to the zebra mussel invasion. The samples will also be analyzed for contaminants.

In August 1994, Charlton conducted surveys of the western basin to determine the impact of zebra mussels on water clarity. Secchi disks, a dredge and a fluorometer were used to establish the correlation between water quality and the presence or absence of zebra mussels. Results showed a large variation in Secchi disk transparency (see contour map this page) over the basin. Many of the dredge samples collected did not contain zebra mussels.

Dr. John Coakley, a research scientist also in the Lake Remediation Project, and Dr. Glenn Brown, University of Toronto, collaborated with Charlton in an experiment to establish the relationship between zebra

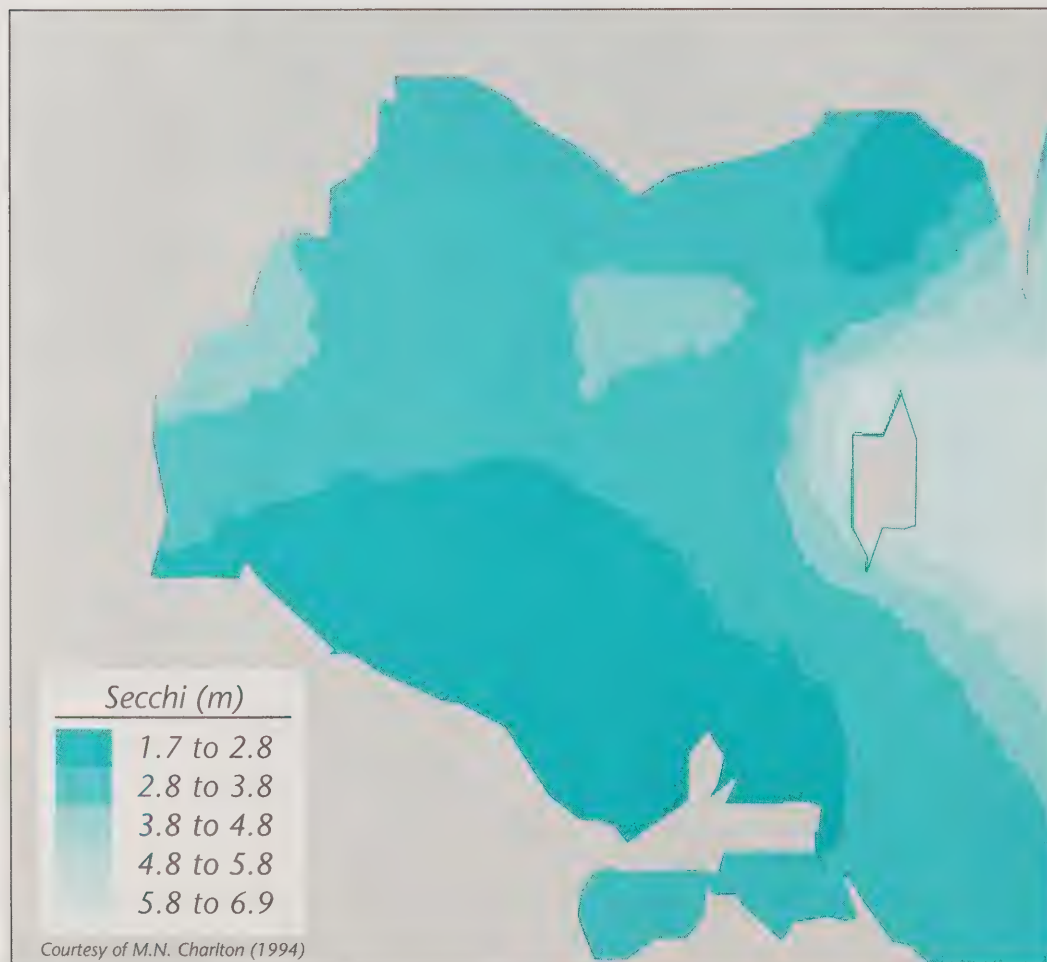
mussel druses (i.e., small colonies) and water quality. Sidescan sonar and underwater video pictures revealed a patchy distribution of mussels, explaining the inconsistencies of the dredge samples. Charlton intends to use remote sensing equipment, in partnership with other NWRI scientists, to develop ways of measuring the extent and duration of clean water events.

The above information gives us only a snapshot of the current work. The table (see top of page 3) outlines the scope of the studies carried out in 1994. Once the analyses are complete, the work will provide baseline information on ecosystem impacts directly attributable to the mussel invasion. Many of the findings will be presented at the next IAGLR conference. 

Contact: Murray Charlton, AERB

Lake Erie West Basin

Secchi depth (m)
contour map,
August 1994




PROJECTED EFFECT	RESEARCH STUDY	RESULTS TO DATE
Modification of sedimenting particles. Increased net sedimentation. Modification of surface sediment.	Deploy sediment traps — compare with previous NWRI data.	Sediment traps installed and retrieved — samples being analyzed.
Lower concentration of algae in water column.	Measure chlorophyll — compare with previous NWRI data and expectations from GLWQA. Complete counts of algae in historic samples.	Chlorophyll measured at 62 stations distributed in each basin. Many values seem similar to mid-1980s but strong reduction effects are seen in some parts of the west basin. Algal counts underway.
More P export from west basin or more P retention in sediments; effects on central and east basins.	Measure TP and SRP in west and central basin exchange areas — mass balance to detect changes — potential impacts to toxic fate.	Total P seems similar to mid-1980s so export is not expected to change but the form of P exported may have changed. Data under analysis may not be sufficient to answer question.
Warming due to more light penetration.	Temperature profiling.	Hundreds of temperature profiles collected. Data need analysis.
Less turbidity.	Turbidity profiling — Secchi measurements.	Hundreds of turbidity measurements with electronic instruments and Secchi disk. About half of the west basin appears to have some clearing effect since 1990. Excellent clarity in much of the lake has existed since the mid-1980s.
Altered DO problem — better? worse? Altered thermocline depressions of oxygen in east basin. Change in west basin?	Profiling — comparison with previous NWRI data.	Oxygen measured with profiling apparatus. Scattered low readings were found but the majority were higher than usual due to the unusual thickness of the hypolimnion. Situation seems within expectations.
Altered nutrient concentrations.	Sample water and compare with NWRI data and expectations to find degree and extent of change due to zebra mussels.	Sampling conducted at 62 or more stations during 12 cruises. Many data are similar to the mid-1980s.
Altered benthos — accelerated recovery of <i>Hexagenia</i> mayflies.	Sample benthos and compare with historical records. Complete enumeration of samples on hand.	Benthos sampled; analyses underway.
Altered nutrient flux from lake bottom.	Continue study of P retention capacity of sediment begun in 1980.	Cores taken for analysis of phosphorus storage capacity.
Microplankton: Changes induced by fish introductions as in Lake Ontario? Extent of mussel coverage.	Sample microplankton — compare with earlier data and Lake Ontario. Map pre-mussel sediment type — map present type and coverage with sidescan.	Sidescan sonar techniques tried. Dredge samples show very patchy distribution of mussels in west basin. Sidescan showed small rocky areas likely to be covered by mussels. Continue census of soft sediments.

Lake Erie Contributions – Department of Fisheries and Oceans

Research scientists from the Great Lakes Laboratory for Fisheries & Aquatic Sciences (GLLFAS), Department of Fisheries and Oceans, survey approximately 45 stations across Lake Erie twice a year, concentrating on the lower trophic levels, in an effort to understand spatial variability at different times of the year and to define regions of the lake. GLLFAS researchers focus on the seasonal dynamics of Lake Erie, as well as species composition and production, to determine the ecosystem response to changes and to the introduction of new species. Studies will feed into an ecosystem model of Lake Erie, focusing on whether or not the lake fishery is sustainable under the current conditions.

The question of a sustainable fishery translates into the energy availability in the Lake Erie ecosystem. There are a variety of different studies which contribute to the determination of energy. GLLFAS scientists monitor change in contaminant flow, phosphorus loadings and the rates of primary and secondary productivity. As part of the Lake Erie Trophic Transfer (LETT)

study, researchers investigate the energy flow and production in benthos, phytoplankton and zooplankton, while measuring phosphorus concentrations. As well, GLLFAS contributes to the development of bio-energetics models to advance understanding of the ecosystem as a whole.

GLLFAS scientists represent another piece in the Lake Erie puzzle. As part of the public service, GLLFAS provides information about energy in the ecosystem and about current and potential constraints on the fishery. The Ontario Ministry of Natural Resources (OMNR), who is responsible for managing the lake fishery, must decide, with the public and industries, how to use the energy and how to apply the acquired knowledge about the lake. All Lake Erie stakeholders (i.e., public, sports fishery, commercial fishery, industry, university sector and government) contribute to making decisions and establishing priorities for sustaining the Lake Erie ecosystem. 

Contact: Ora Johannsson or Scott Millard,
GLLFAS

GLURF 1994

GLURF Award Recipients 1994

T.A. Abrajano

Memorial University

Isotopic (^{13}C) validation of models of polycyclic aromatic hydrocarbon sources in Lake Erie adjacent ecosystems

P.G.C. Campbell

Université du Québec

Trace metal cycling in pelagic waters of Lake Erie: rate of picoplankton and influence of grazing by microzooplankton

H.C. Duthie

University of Waterloo

Long Point wetlands: formation history and response to climate change and Lake Erie water levels

G.D. Haffner

University of Windsor

Energy flow and contaminant dynamics in the Lake Erie ecosystem

B. Kueper

Queen's University

Mass loading of immiscible liquids from contaminated groundwater systems to open water bodies

M.R. Lowen

University of Toronto

Benthic pelagic coupling in zebra mussel beds: assessing the impacts of an introduced species in Lake Erie

A. Weersink

University of Guelph

Controlling agricultural water pollution under uncertainty

The Great Lakes University Research Fund (GLURF) was a four-year Environment Canada grant program intended to promote multidisciplinary ecosystem research and develop research partnerships between universities and government agencies. Ongoing research at the Canada Centre for Inland Waters indicated rapid changes taking place in Lake Erie, so NWRI allocated the last year of GLURF as part of the effort to reassign resources to meet the lake's immediate challenges. The fourth year of GLURF has been successful in bringing together a consortium involving over 40 scientists to define problems in the Lake Erie ecosystem.

The largest of the GLURF projects was led by Dr. Douglas Haffner from the University of Windsor's Great Lakes Institute. Dr. Haffner coordinated the combined forces of several research groups to study energy flow and contaminant dynamics in the Lake Erie ecosystem. A comprehensive survey of Lake Erie was completed in 1994 in a partnership of Environment Canada, Fisheries and Oceans and Canadian universities. The success of this partnership will result in a "snapshot" of Lake Erie trophic structure, energy flow and contaminant dynamics.

Dr. Haffner led a team which examined benthic/pelagic coupling, while his colleagues, Dr. Gary Sprules, University of Toronto, and Dr. W. Taylor, University of Waterloo, directed studies of energy flow dynamics


and implemented the investigation of water column contaminant dynamics, respectively. Integration of the findings during 1995 will be achieved through workshops, conference sessions and the use of mathematical models.

Dr. Sprules leads the team which quantifies energy flow in the Lake Erie food web. Extensive information was collected on the spatial and temporal distribution of zoo-

plankton and fish using a towed optical plankton counter and a dual-beam echosounder. The results are being combined with studies of fish population structure, zebra mussel effects and planktonic productivity and distribution to yield a picture of energy flow within the lake ecosystem.

Dr. Taylor's team determines water column dynamics, including estimating the importance of mesozooplankton and nanoplankton grazing, in a focused approach directly complementing Dr. Sprules' surveys. Detailed analysis of productivity and grazing in pelagic biota will yield information on the relationship between food web structure and concentrations of hydrophobic contaminants (i.e., organochlorines).


Dr. Haffner quantifies benthic/pelagic coupling and estimates the importance of these processes in regulating contaminant burdens in sport fish and fish-eating birds. Contaminant concentrations in various compartments (e.g., benthic invertebrates, benthic-feeding fish, plankton, forage fish, piscivores, fish-eating birds, macrophytes, archived cormorant eggs, etc.) are being analyzed to establish spatial distributions and contaminant dynamics. These are being supplemented with testing of genotoxicity, cytotoxicity, EROD induction and emergence of insects.

Various hypotheses are being generated and tested within these apparent "shotgun" approaches. A major constraint in achieving general insights is the extent of spatial and temporal variability observed within the lake. As analyses are completed and the process of interpretation and synthesis takes place over the coming 2-3 months, the GLURF researchers will be developing the information upon which a lakewide management plan can be based. 

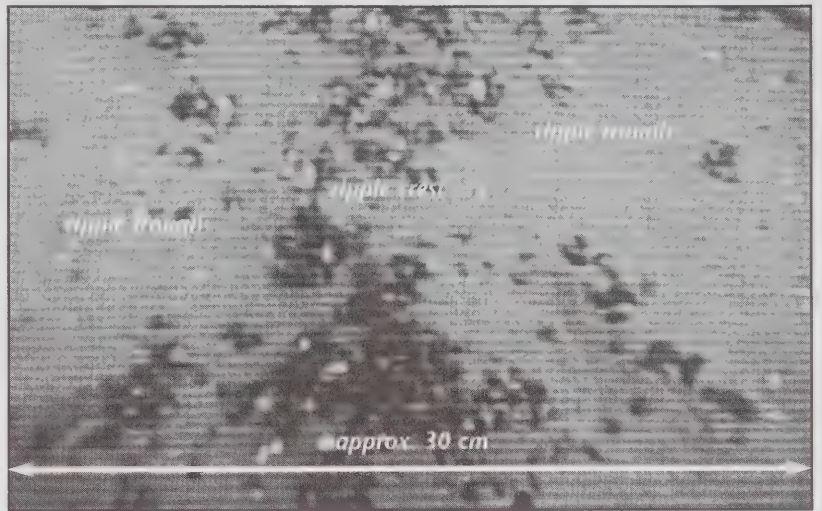
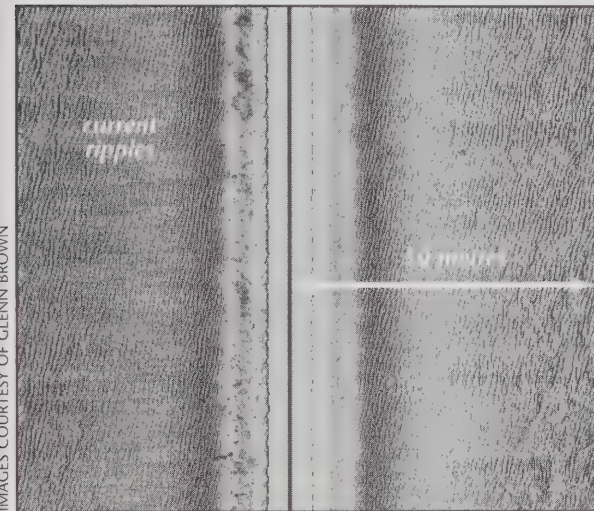
Contact: Hague Vaughan, AECEB

Acoustic Imagery Technology

NWRI scientists use acoustic imagery technology (i.e., sidescan sonar) to improve methods of quantifying the zebra mussel population in western Lake Erie. The sidescan technique visualizes objects, such as zebra mussels, by sound, not by light, thus magni-

fying previous video efforts by a factor of 10. The sound source on the ship transmits energy in a fan-shaped pattern on either side of the ship. The greater the amount of energy reflected back, the darker the image. 

Contact: John Coakley, AERB



Organic Contaminants and Zebra Mussels


The changes in Lake Erie attracted attention when researchers observed shifts in animal populations and a dramatic change in water clarity. Michael Fox of the Aquatic Ecosystem Restoration Branch (AERB), who had been monitoring the presence of persistent manufactured organic compounds (e.g., organochlorines, pesticides, PCBs) in the lake, was especially concerned with how these significant changes would affect the distribution of contaminants.

Working in collaboration with Trent University, Fox's team of researchers and students collected large samples during 1994 — in the spring, early summer and late summer. The samples came from a transect of five stations in the western basin of Lake Erie. Zebra mussels prefer the shallow water of the western basin, and their abundance there had drastic effects on the community structure of the lake's wildlife. Researchers filtered the extracted samples and kept the dissolved phase (after filtration) and the particles on the filters for each sample.

Fox theorizes that filter-feeding zebra

mussels affect not only the amount and nature of suspended solids, but also the distribution of organic contaminants through the water, the suspended solids, the biological community and the bottom sediments.

In this particular study, researchers will look at selected organic contaminants (some PCB congeners, pesticides and some other industrial organochlorine compounds) and compare the distribution of those contaminants between the dissolved and particulate phases. The study encompasses data collected prior to the zebra mussel invasion and during the 1994 research program. The team will ascertain if zebra mussels intensify the process by which settling particles carry contaminants to the bottom.

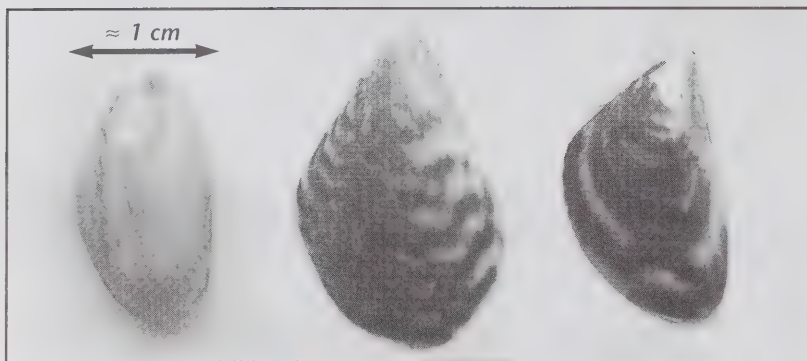
AERB researchers are beginning the first stage of analysis on the extracted samples. Fox anticipates the completion of a report on the study by the end of the year, including a summary and preliminary interpretations of the findings. 

Contact: mike.fox@cciw.ca

Left: Sidescan imagery of bedforms (ripples). Right: Close-up of similar bedforms imaged using a towed video recorder. Ripple crests appear to be preferential sites for zebra mussel colonization.

Zebra Mussel Studies in Lake Erie

PHOTO BY RON DERMOTT



Left to right:
Dreissena polymorpha, normal zebra mussel, Marsden's "Quagga" mussel.

Recognizing the seriousness of the zebra mussel invasion of Lake Erie, scientists realized the need to assess the impacts of the species on the aquatic ecosystem. During the summer of 1994, researchers from NWRI's Aquatic Ecosystem Conservation Branch (AECB) and Aquatic Ecosystem Restoration Branch (AERB) examined physical data taken

from Lake Erie as a component of a two-part study of the lake.

One part of the research focused on wind and other surface meteorological variables, including solar radiation, at a central point in each of the lake's three basins. Additionally, currents and water temperatures were measured at two points in the vertical at each station. Data were collected continuously at 10- to 20-minute intervals from May to September.

AERB scientist Dr. Paul Hamblin led a university-based research team in the second part of the study that directly observed currents, waves and chlorophyll *a* profiles in the vicinity of an infested reef in the western basin over an intensive period of several weeks.

Both field programs are currently in the data analysis phase. ➤

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Impact of Agricultural Pesticides on Coastal Wetlands

Coastal wetlands on the Canadian side of Lake Erie represent an important and unique ecosystem. There is a growing concern for the preservation of the ecosystem and for the protection of the habitats provided for many plant and animal species. Alena Mudroch of the Aquatic Ecosystem Restoration Branch (AERB) is especially concerned about the potential danger to the wetlands from pesticides and nutrients from intense agricultural activities.

Mudroch's group at NWRI, in cooperation with Agriculture Canada, conducted a multidisciplinary study from 1992 to 1994, evaluating the distribution and transport of contaminants, particularly pesticides, from agricultural land into Lake Erie coastal wetlands. The ensuing report contains results from a part of the study which focused on temporal and spatial distribution of pesticides in water, suspended particulate matter and bottom sediments at selected streams in the vicinity of the wetlands.

The study results indicated that pesticides were transported from surrounding creeks


draining into the wetlands and the nearshore zone; the pesticides were carried mainly by water, with some transport by suspended particulate matter. The concentrations of pesticides in the bottom sediments showed a continuous transport of sediment-associated pesticides downstream into Lake Erie. Analyses detected alachlor, a pesticide banned in 1989, in the suspended particulate matter at one of the sampling stations. The highest concentrations occurred between May and July, immediately following the pesticide application on the fields and the increased spring precipitation.

Chronic exposure of the marsh and lake biota to these concentrations of pesticides, as well as the cumulative effect, continues to be a research focus as scientists and decision-makers evaluate the effects of pesticides released from agricultural activities on Lake Erie coastal marshes and nearshore area. ➤

Contact: Alena Mudroch, AERB


Reference: Bourgoin, B.P. (in memoriam), A. Mudroch and G. Garbai. 1995. Distribution of pesticides in streams and wetlands on the north shore of Lake Erie. NWRI Contribution No. 95-01.

Lake Erie Lakewide Management Plan (LaMP)

In September, 1994, eighteen Canadian and U.S. agencies met in Chicago to initiate the process for developing a Lake Erie Lakewide Management Plan (LaMP). Following the example of other LaMPs already in operation, the Lake Erie LaMP focuses on protecting and restoring the lake's valuable resources and uses, according to the guidelines of the *Great Lakes Water Quality Agreement* (GLWQA). This collaborative bi-national effort looks at current or potential environmental stressors such as the influx of critical pollutants and exotic species, and habitat loss. LaMP coordinators encourage cooperation with and contribution from the general public through a variety of public education and outreach programs. 

Contact: Sandra George, Ontario Region, Environmental Conservation Branch

In the Spotlight...

The wealth of data from Lake Erie, combined with NWRI's success in modelling water quality, has been instrumental in the selection of this lake as a focus for research by the Task Force for Forecasting Environmental Change at the International Institute for Applied Systems Analysis (IIASA). Lake Erie has also been chosen as one component of the Great Lakes-St. Lawrence Basin Project (GLSLBP) and the Great Lakes 2000 investigation of prevention/mitigation of climate change impacts. 

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1994 Vollenweider Lectureship


January 5, 1995, Dr. John P. Giesy, Distinguished Professor of Fisheries and Wildlife, Michigan State University, presented the 1994 NWRI Vollenweider lecture entitled "Polychlorinated Diaromatic Hydrocarbons in the Environment: Implications of Global Contamination."

Professor Giesy is an aquatic toxicologist with interests in many aspects of the field, including the fate and effects of potentially toxic compounds and elements. Ecotoxicology and wildlife toxicology are relatively new fields of endeavour. It remains difficult to establish cause-effect linkages between exposure of wildlife to synthetic compounds and observed population-level effects. Wildlife is exposed to a complex suite of contaminants, the relative composition of which changes spatially and temporally and with trophic level.

Dr. Giesy currently studies the toxicity and reproductive effects of organic compounds on fish and fish-eating birds and mammals in the Great Lakes region. His work is closely linked with many of NWRI's current research projects.

NWRI established the Vollenweider Lectureship in Aquatic Sciences in 1988 in



honour of Dr. Richard A. Vollenweider. The award is granted annually to an eminent freshwater scientist who has made a significant contribution to the field of aquatic sciences. 

Contact: janet.cooley@cciw.ca

Dr. Ralph Daley (right), Executive Director of NWRI, presents the 1994 Vollenweider award to Dr. John Giesy.

NWRI has developed a variety of specialized computer software packages of particular interest to environmental agencies, consulting firms, universities and industries. NWRI Software has been established to market and distribute the licensed and public domain software available from the Institute. Three software packages are currently available: **RAISON**, **EXPRES** and **COMPUTOX™**.

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NWRI Digest is the public newsletter of the National Water Research Institute, Canada's largest freshwater research establishment. The Institute conducts a comprehensive program of research and development in the aquatic sciences, which it undertakes in partnership with water management agencies and water science communities in Canada and around the world. This research creates knowledge and develops expertise on water quality issues important for sustainable water resource use and the preservation of freshwater ecosystems.



Suggestions, comments and further enquiries concerning *NWRI Digest* are welcomed. Articles may be reprinted upon permission from the editor. Please write to:

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